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THE HUMAN SEEING-MACHINE.

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An unusual experience may have an unusual effect upon a specific individual; but, in general, human beings are affected most by the more commonplace factors. Such factors of natural environment have left their effects upon all human beings exposed to them during the eons of evolution. In a similar manner activities of human beings and factors in the artificial environment of civilization leave their imprints. Seeing is a universal activity of human beings and many factors upon which it depends are controllable. Some of these factors have been greatly altered by civilization, and human beings are paying the penalty of indifference and lack of knowledge. Scientific research has gone far in many directions; but it has woefully neglected the human seeing-machine. No science is more needed by human beings than the science of seeing; and none is more promising in its benefits.

For many years the eyes and, more broadly, the visual sense have received much attention. As a consequence, a great deal is known pertaining to the optics of the eyes and to the functions and limitations of the visual sense. Upon a well-defined science of vision, eye-specialists have established an excellent service to human beings. Optometry supplies

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lenses which correct optical defects so prevalent in human eyes and ophthalmology takes care of pathological conditions. Thus, much scientific knowledge and practical experience are available to care for the eyes. Just as eyesight is the most valuable and generally used sense of human beings, seeing is the most important and universal controllable activity. Eyes are deserving of all the attention they need, but this should not blind modern science to the more important end-product which is seeing. From the broader viewpoint of seeing eyes are merely tools, regardless of their great value.

Seeing is nearly as complex as living. Human beings are dependent upon it for most of their usefulness and for much of their happiness. They even think visually. Words and language are chiefly the means of developing word-pictures or mental images. Notwithstanding the universal dependence upon, and dominance of seeing, only a rudimentary science of seeing exists. In scientific research as well as in practice, a consideration of seeing seldom goes beyond the eyes into the internal realm of the human seeing-machine. A human being is a seeing-machine whose important tool is the visual sense. Considered as machines, human beings have a right to know how much it costs them to see. Usually the value of seeing is more or less evident; but the cost is hidden in the maze of internal effects, obscure and subjective. How these effects manifest themselves must be answered by studies of the complex human organism. The efficiency of a human seeing-machine is not measured by the common unit of useful work per hour or per dollar. It is properly measured by the ratio of the output to the input, as in the case of inanimate machines. In other words, the useless internal work, analogous to friction losses, should be measured. These physiological effects are a drain upon human resources. And finally, human seeing-machines are *human*, experiencing psychological effects through the eyes and visual tasks. In the study of seeing a complexity of psycho-physiological effects must be unraveled. The science of seeing thus becomes fascinating in its intricacy and perhaps unsurpassed in importance to civilized human beings.

The development of a science of seeing must begin with a consideration of the natural environment under which

human beings evolved. The eyes, the visual sense, and the psycho-physiological being are adapted to that environment. Light is the outstanding partner of vision in the activity of seeing. Natural light of a spectral character within a certain range is available outdoors in quantities up to 10,000 footcandles. The light comes from a broad expanse of sky and from a single powerful source, the sun. Usually from 10 to 20 per cent. of the total light on clear days comes from the sky and, of course, 100 per cent. on overcast days. Apparently, the physiognomy of human beings has been molded, partially at least, for shading the eyes from brightness overhead. Just as many apparently innate psychological powers of color have their source in the commonplaceness of their hues, locations and prevalence outdoors, so are the psychological effects of natural light, lighting and brightness-distribution traceable to naturalness.

Indoors, great alterations in all these factors have resulted from the character of artificial structures. Artificial light differs markedly in spectral character and both by day and by night the lighting is far different from that outdoors. Reflection-factors outdoors are generally low. White paper is an artificial product of relatively high reflection-factor and it is the background of a universal visual task—reading. White paper in direct sunlight is doubtless too bright, at least it is unnaturally bright. Therefore, the highest intensities of illumination outdoors are perhaps far too great for comfort when reading black print on white paper. On the other hand, many visual tasks indoors involve low reflection-factors. Certainly any common visual task indoors needs more than the few footcandles generally found indoors.

It is also necessary to consider the activities and use of the eyes outdoors and particularly during the uncounted thousands of years while primitive man was evolving. The eyes were not subjected to long periods of continual near vision. Convergence of the eyes is an acquired characteristic and certainly far vision (looking at objects twenty feet distant or more) is less fatiguing than near vision. There is no proper distance for near vision. The accepted distance is dictated by convenience within the reach of the arms. Still, modern civilization imposes many hours of near vision

upon human seeing-machines daily, under greatly restricted intensities of illumination and light often differing greatly in quality from that outdoors. It is possible and even likely that outdoor light and lighting may be improved upon by mankind, but it remains for a science of seeing to show how. Until knowledge is available, certainly natural environmental factors can safely be depended upon and the burden of proof rests upon departures from them.

A prevalence of eye-defects can scarcely be considered to be natural. Arms and legs, muscles and brains develop from daily use and are generally normal. It is unnecessary to admit that eye-defects are natural when there is so much neglect of factors upon which good seeing depends. Many accidents of staggering figures in lives, limbs and property are known to be due to low visibility. But besides these obvious objective results, is it not likely that the every-day drain of human resources is a staggering total? Why do human beings tire who are engaged in serious visual work all day long? Is it not possible that much of this fatigue is due to unnecessary handicaps of poor seeing?

There are many external factors which influence seeing. A universal one is quantity of light. The effect of intensity of illumination upon the useful work done by workers has been studied. The general form of the production curve,[1] as influenced by intensity of illumination, is shown in Fig. 1. It represents the efficiency of the worker as determined in the narrow sense of useful output. It is no measure of the efficiency of the human seeing-machine. Several years ago we developed Fig. 1 as a tentative diagram of the human seeing-machine.[2] Along the base line any seeing factor could be plotted. Therefore, this diagram may be considered a slice of a three-dimensional diagram, this slice representing the factor, intensity of illumination. Inasmuch as the production of workers usually ceases to increase appreciably at 20 or 30 footcandles, this could not be accepted as evidence that no more benefit was to be obtained by further increases

[1] "Light and Work," by M. Luckiesh, D. Van Nostrand Company, New York, 1926.

[2] "Seeing—A Partnership of Lighting and Vision," by M. Luckiesh and Frank K. Moss, Williams and Wilkins Company, Baltimore, 1931.

in quantity of light, considering the enormously greater intensities of illumination outdoors under which human beings evolved.

With some qualitative data, supported by experience and philosophy, the upper part of Fig. 1 was evolved.[3] The upper curve indicates that with increase in intensity of illumination (or improvement of any seeing factor) the task becomes easier even though production ceased to increase appreciably. In other words, the internal useless work of the human seeing-machine decreased as seeing was improved. Since then, excellent quantitative proof has been obtained over a range of intensities of illumination from 1 to 100 footcandles,[4] even though the visual task could be performed, apparently with ease, at one footcandle. Thus, Fig. 1 became more than a mere diagram. It became a new viewpoint of seeing, a specimen diagram of the human seeing-machine. It is a glimpse of a new theory demanded by various facts and experiences.

This introduction to a subject almost as complex as living is a meager sketch, but at least it reveals the need of a new science, the inadequacy of the present viewpoint of vision and the neglect of modern science in regard to the efficiency, behavior and welfare of human beings as related to the universal activity of seeing. With the development of such a science this half-seeing world which is paying a penalty, partly known and doubtless largely unknown, will be eventually served by seeing specialists. Certainly social scientists must include seeing and not merely eyes in their considerations.

A SCIENCE OF SEEING.

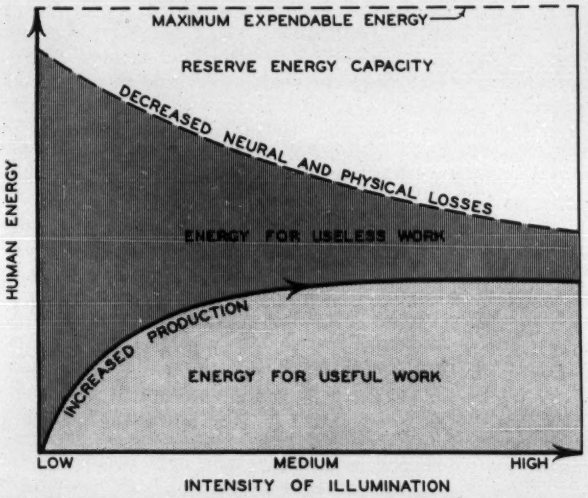
Seeing involves a chain of complexities more or less entwined. There is a chain of events beginning with the physical object and the stimulus, which is light. Next is the sense-organ process limited by the peculiarities and functions of the eyes and retinae. The nerve stimulation is followed by nerve activity which reaches the brain centers

[3] "The New Science of Seeing," M. Luckiesh and Frank K. Moss, *Trans. I. E. S.*, **25**, 15, 1930.

[4] "The Human Seeing-Machine," M. Luckiesh and Frank K. Moss, *Trans. I. E. S.*, **27**, 699, 1932.

and perception or recognition of the object is achieved. But this is not the end. It is more like the beginning from the viewpoint of human beings, for it opens into the important realm of end-products which has been neglected because scientific studies and practical applications have dealt with the visual sense instead of the activity of seeing. The ultimate end-products are human efficiency, behavior and

FIG. 1.



A diagrammatic view of the expenditure of energy by a human being engaged in a visual task. Any of a number of seeing factors could be placed on the horizontal scale. Intensity of illumination is always a factor and, in the present primitive stage of lighting, is the most generally important factor. The lower and upper curves in the diagram are typical of the external or physical and the internal or psycho-physiological realms of seeing, respectively.

welfare. Knowledge of these and the ability to prophesy results of specific conditions are the final objectives and obligations of a science of seeing.

For the purpose of analysis and measurement seeing may be divided into three complexities:

1. The external physical realm, consisting of many factors and combinations of them, such as light, lighting, color,

brightness, object and surroundings, which influence visibility. All these eventually play parts in human efficiency, behavior and welfare.

2. The eyes or visual sense, which is a physico-physiological complexity of various parts and functions, such as the pupil, optical system and photosensitive retina. The abilities, limitations and mutual influences of the parts and functions determine the efficiency and welfare of this mechanism and eventually of human beings.

3. The internal psycho-physiological realm, consisting of the mental processes as a part of the visual sense and the resulting physiological and psychological effects, such as discomfort, fatigue, nervous muscular tension, utilization of human resources, ability to concentrate, degree of stimulation, and even attitude and happiness. The end-products determine the cost and value of seeing, and the knowledge and impressions gained from the external world.

Even a superficial consideration of the foregoing reveals an extremely complex science of seeing involving several sciences. The external factors are physical and, therefore, more readily measured and understood. For this reason they have been over-emphasized and in most scientific and practical considerations of seeing the physical aspects of visibility factors have received attention to the exclusion of the other important realms. But even in the external physical realm there are so many factors that numerous relationships must be considered. Furthermore, it is impossible excepting by means of higher mathematics, to show the relationships of more than three factors at a time. Even when color of objects and spectral character of light are excluded, there is an extensive complexity. This same complexity exists for each color and spectral character. The approach is best made by eliminating these in the initial research or consideration. Then they may be superposed. The fundamental basis and factors may ignore color and, although color-vision is of more importance than is commonly recognized, it is safe to say that color and spectral character are generally of secondary importance in every-day seeing.

One of the outstanding demands of a science of seeing is that threshold data, or seeing under threshold conditions,

ceases to hold the center of the scientific stage and that attention be given to the study of optimum conditions. Threshold data are of importance in establishing the ultimate limit of seeing, but every-day seeing is done above the threshold. Furthermore, adequate factors of safety should always exist, but their magnitude cannot be specified until the minimum requirements for optimum conditions are known. A new viewpoint and new research methods must be created if a science of seeing is to be developed.

Controlled laboratory researches must develop the science of seeing, but they also must be depended upon for appraising seeing conditions. This point is emphasized because it is a very common error for human beings to assume that they are judges of seeing. Unfortunately, seeing-meters are not available as thermometers are for appraising temperature and scales for weighing. And there is no prospect of their development, owing to the psycho-physiological complexity of seeing. Although one is able to see or to perform a visual task, even a commonplace task such as reading, one is unable to appraise the *ease* of seeing. In other words, the effects of various seeing factors must be interpreted into practice from laboratory researches. As seen in Fig. 1, the production of useful work is an inadequate measure of seeing. To some extent it may measure the ability to see and the certainty and accuracy of seeing; but it does not measure the ease of seeing or the efficiency of the human seeing-machine as such.

There is a great mass of data available from pathology, physiology, psychology, philosophy and experience. But most of this knowledge came from isolated researches or is dominated by the restricted viewpoint of eyes or vision and usually consists of threshold data. Viewing these data from the broader view of a science of seeing, some of them can be coördinated into the complete picture, although in general the conclusions originally drawn from the data must be modified. The new foundations constructed from these data and from the data yielded by researches in seeing provide a guide for future researches so much needed in closing the gaps in the knowledge of seeing.

At best only elementary knowledge of the integrated and ultimate effects of visual effort is available. Threshold data

must be demoted to secondary importance, for they represent limiting conditions. At present, the available data pertaining to optimum conditions from the viewpoint of the human seeing-machine are so meager that no one can write the specifications for the various factors of seeing which represent maximum efficiency at the least cost in human resources for performing any specific visual task. However, the science of seeing has already progressed far enough to indicate that seeing conditions, object, contrast and backgrounds, are of a low order devoid of adequate factors of safety and uncomprehended from the viewpoint of human seeing-machines and their resources. The lack of scientific knowledge of fundamental factors and their relationships and effects is obvious in the critical contemplation of any specific task. It becomes greatly emphasized when one considers the enormous variety of visual tasks and the difference among human seeing machines whose visual tools may be young, old, defective, average or normal adult eyes.

No one who has intimately and deeply considered the complexity of seeing as a human activity can doubt the need and beneficence of a science of seeing. However, in the present crude stage of this science it is difficult to demonstrate the cost and value of seeing. At best, a demonstration can deal with only a few of the factors. Furthermore, seeing is elastic, varying from moment to moment with the focus of eyes and attention. And finally, time is an important element, generally neglected in conclusions from researches on eyes and vision. It takes time to deplete human resources and to abuse the human seeing-machine so as to produce noticeable fatigue and nervous muscular tension, headaches and various other effects of continued seeing. Therefore, casual appraisal, or even measurements, of visibility do not integrate the effects of time. Doubtless, as the science of seeing develops, demonstrations of some phases of the many problems will be devised. However, it must be recognized at the outset that indicating instruments are not integrating devices. The former can only be depended upon to prophesy the final integral effects upon human beings when the correlations are fully developed by tedious researches in the psycho-physiological realm. This absence of demonstrations

is a great handicap at present in efforts to extend the narrow viewpoint of vision into the broad and adequate one which deals with human seeing-machines. But their ultimate limitations need not be discouraging if one views the development of a science of seeing with these limitations in mind.

There are two ways of developing a science and, where human beings are involved, these two are usually in action simultaneously. One begins at the foundation and applies modern scientific method in controlled researches. The other yields at least qualitative data from studies of the results of practice. This includes mass experience, indefinite as to the individual but becoming more definite for the mass. Scientific analyses are already coördinating the results of isolated researches in various sciences which have a bearing upon seeing and upon the human seeing-machine. Also, new researches from the new viewpoint are already contributing fundamental data.

In the world of human activity much experience with various seeing factors has been, and is being, obtained. In lighting, printing, signaling, automobiling and throughout the world of work, a mass experience is already available. Some of the effects of poor seeing are recorded in impaired eyesight and health, in accidents in industry and on the street, in poor production in the work-world, and in various effects of abuses of the human seeing-machine, such as undue strain and fatigue. As the science of seeing develops, the appraisal of these practices and results will be done with fuller meaning. One of the best examples is lighting, which has greatly developed during the present century owing to the advent of more efficient and adequate light-sources. Viewed from the common but inadequate viewpoint of the physics of light, great progress has been made. However, from the viewpoint of the science of seeing, lighting everywhere in the artificial world is in a very primitive stage.

Light is the one factor of seeing which is always present and essential in the performance of a visual task. Lighting is the outstanding partner of the visual sense. This partnership alone must eventually account for most of the complete science of seeing. Still, lighting in its broad sense of proper quality, quantity and distribution is seldom available. So-

called lighting specialists usually provide only light and this with very little knowledge of seeing and certainly up to the present time with little, if any, conception of the overwhelming importance of the psycho-physiological effects upon human seeing-machines.

Eye specialists have advanced far in the production and supply of lenses which correct refractive errors in the eyes. They sharpen the visual tools, but generally they do not follow these tools and human seeing-machines into the world of active use. As they grasp the significance of the new science of seeing, they will do so and there will be a metamorphosis from the eye specialist into the seeing specialist.

A CONSIDERATION OF MEASUREMENTS.

Quantitative measurements and formulated knowledge in the sciences represented in the chain of complexities in seeing vary from the precise and absolute data of the physical sciences to the variable and relative data of the psycho-physiological sciences. In view of these facts it is not to be expected that the end-products resulting from the functioning of the visual sense may be stated in simple empirical terms for various visual conditions and tasks.

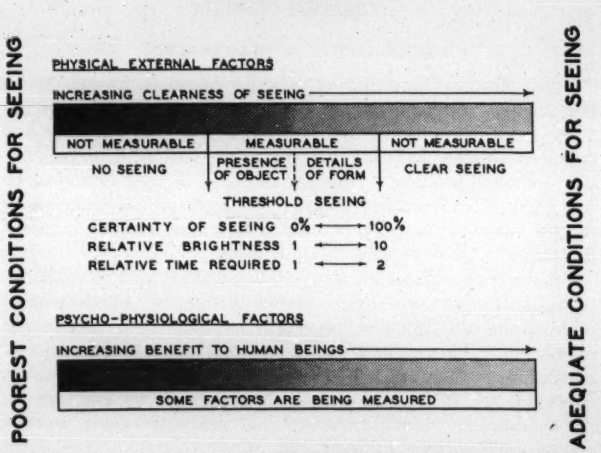
A diagrammatical view of the limitations and possibilities of measurements in seeing is shown in Fig. 2. The left-hand edge of the diagram may represent inadequacy of any factor of seeing. The right-hand edge represents adequacy of conditions for seeing. The upper portion of the diagram is confined to the socalled external factors measurable in physical units. It will be noted that visibility measurements are possible only in a limited region.[3]

Suppose that intensity of illumination is the factor under consideration. Beginning with no light, this factor is gradually increased. No measurements can be made until there is enough light to distinguish the *presence* of the object. As the intensity of illumination is increased, eventually the object can be *recognized;* that is, distinguishing details can be seen. The point at which the object is barely recognizable is the threshold condition for intensity of illumination and all other factors involved. As the intensity of illumination is increased, the certainty of seeing increases until finally it

becomes 100 per cent. No further measurements of visibility can be made as the intensity of illumination is increased. But this does not mean that higher intensities do not make the task of seeing *easier* for the human seeing-machine. In fact, researches arising from this new viewpoint show that the task does become easier.[5]

In the lower part of Fig. 2 is represented the complexity of psycho-physiological factors which may be considered to

FIG. 2.



A diagrammatic representation of the two general types of measurements in the science of seeing and their respective limitations.

be largely internal. As conditions for seeing improve, there is increasing benefit to human beings engaged in visual tasks. Some of these factors are being measured either alone or as a part of an unseparated group. It will be noted that these

[5] "A Correlation Between Illumination Intensity and Nervous Muscular Tension Resulting from Visual Effort," M. Luckiesh and Frank K. Moss, *Jour. Exper. Psych.*, October, 1933. "Muscular Tension Resulting from Glare," M. Luckiesh and Frank K. Moss, *Jour. of Gen. Psych.*, 1933.

measurements, although difficult to obtain, are not restricted to threshold values. Hence, their interpretation is relatively easy and direct in comparison with the threshold measurements of the external realm of seeing.

If human seeing-machines were capable of adequately appraising the expenditure of human resources required for seeing and the efficiency with which they functioned, the mass of experience acquired through the ages would preclude the necessity for formal measurements of seeing and the results of this activity. The simultaneous existence of universally defective vision and unnecessarily primitive conditions for seeing indict human beings as very poor "seeing meters." Although Nature provides the visual apparatus with certain protective devices, these facilities are ineffectual in protecting the eyes, nervous system and other human resources from the abuses arising from artificial environments. Measurements in seeing are for the purpose of revealing the handicaps under which the eyes are operating and to assist in prescribing and securing optimum conditions for human seeing-machines.

Measurements forming the structure of the science of seeing include, besides visibility, those typical of the field of psycho-physiological optics and, in addition, involve a new series of measurements pertaining to the welfare of the human subjects, insofar as welfare and behavior are influenced by the functioning of the visual sensory process. The technique and criteria for the study of the visual functions have been well established and an extensive background of reliable data is now available. Criteria for the quantitative appraisal of the welfare of human seeing-machines are being developed. However, at present, basic data applicable to this field are meager in comparison with their importance.

The physical, physiological, and psychological complexities in seeing are such as to eliminate the possibility of a single experimental criterion which would integrate all phases of seeing and which would permit an adequate interpretation of the experimental results. Even if the subject is subdivided into its several major components, as previously defined, it has not been possible to reduce these phases to measurement by the application of single respective criteria. Hence, it is

necessary to resort to various more or less indirect criteria in each phase and such criteria have been proposed or used in great diversity. Analyses of the reliability, applicability and meaning of these criteria have constituted an important step in the development of a science of seeing.

Attempts have been made to measure eye-fatigue, but neither has it been satisfactorily isolated nor is it an adequate measure of fatigue of the human seeing-machine. It is conceivable that an accurate and sensitive measurement of general bodily fatigue would serve as a general criterion for the appraisal of seeing conditions, if such a measurement could be made. This criterion would summarize the complete effects produced by the expenditure of muscular and neural energy in the process of seeing. These end-products obviously would be a function of the visibility of the objects to be seen, the duration of the visual task, the condition of the ocular apparatus, and the psycho-physiological responses of the subject to visual stimulation. The diagnostic value of such a datum for revealing the inadequacy of seeing conditions now generally prevalent is obvious. However, a method for determining this datum is not now available.

As a practical substitute for the theoretically ideal appraisal of general bodily fatigue, certain indirect and restricted criteria have been proposed or used. For example, nervous muscular tension,[5] developed incidental to the process of reading and appraised by increased tension in the muscles of the fingers, proved to be a valuable addition to the experimental technique of the science of seeing. In addition to registering the end-products of photosensory stimulation, such criteria are important because of the directness and simplicity with which the experimental results may be interpreted into practice. In this respect, the indirect measurements of fatigue are far superior to visibility data as means for determining the adequacy of conditions for seeing.

Representative criteria employed in the science of seeing are presented in the following outline:

Measurements of Seeing Can be Made in Two Realms:

At Threshold Conditions	*Above threshold conditions*
Unusual in everyday seeing	Usual in everyday seeing

Usual in research technique	Unusual in past research technique
Restricted range of applicability	Unrestricted range of applicability

A direct method of integrating and expressing the effects of visual effort upon the human seeing-machine is not available at present. Hence, the following are representative, more or less indirect, criteria which have been or could be used for appraising seeing conditions and their effects upon the human seeing-machine.

Characteristic Criteria:

At Threshold Conditions

Absolute sensitivity to light
- Minimum radiation visually perceptible
- Time and areal relationships of photosensory stimulation
- Retinal sensitivity correlated with ophthamologic findings

Sensitivity to brightness-difference
- Contrast sensitivity related to photometric characteristics of the visual stimuli
- Size and duration of stimulus on the contrast sensibility of the retina
- The influence of adaptation upon contrast sensitivity of the retina

Visual acuity
- As a function of area, form and distance of test-object
- Related to photometric characteristics of visual stimuli
- Related to dioptrics of the eye
- Related to oculomotor functions of the eye

Duration of stimulus for retinal impression
- Brightness, size, contrast and time relationships for photosensory stimulation

Growth and decay of brightness sensations
Intermittent stimulation effects

Certainty of seeing
Related to photometric characteristics of visual stimuli
As a function of duration of visual stimuli

Above Threshold Conditions

Physiological criteria
Nervous muscular tension
General bodily fatigue
Fatigue of the eye-muscles
Retinal fatigue
Pupillary changes
Cardiac reactions
Oxygen consumption

Psychological criteria
Psychological effects of surroundings
Subjective appraisal of ocular comfort
Influence of light upon tactile discrimination
Influence of the simultaneous stimulation of the visual and other senses
Mental and motor efficiency
Concentration on task
Analysis of visual illusions

Pathological criteria
Pathological effect of illumination intensities
Effect of invisible radiation upon the eye
Ocular symptoms of faulty illumination
Analysis of data concerning defective vision

Efficiency of motor processes
Precision of visually controlled operations
Rate of performing visual and visually controlled operations
Reaction-time measurements

Kinematic criteria
- Fixational pauses of the eyes
- Eye-movements related to difficulty of seeing
- Visual perceptual processes
- Perception of motion

Other visual functions
- Perception of depth and distance

The visibility of objects is fundamentally determined by their size, brightness, contrast with background and time available for recognition.[6] Upon this complicated situation are imposed the complexities of color, spectral quality of radiation, and the physiological and psychological influences of the surroundings. This entirety is viewed with eyes which vary in capability over the wide ranges common to the biological realm. Laboratory researches are arranged to investigate certain characteristics common to a large number of visual situations, but not necessarily involving all of the factors of the individual case. Hence, experimental results inherently require interpretive treatment in order to be applicable to practice. For this reason, even the most specific and precise research data may seldom, if ever, be isolated from the restrictions imposed by the research technique and presented or used in handbook style.

The difficulty of interpreting such data naturally varies with the directness with which the experimental criteria appraise the specific case. Usually, two or more interpretive steps are required in order to apply measurements of seeing to actual conditions for seeing. The major phases of the interpretive process are as follows:

From threshold conditions of seeing to usual conditions of seeing.
From brief test-periods to extended periods of visual effort.
From specific criteria of seeing to the influence upon the entire human seeing-machine.
From normal eyes to abnormal eyes, or *vice versa*.

[6] "Four Variables of the Visual Threshold," P. W. Cobb and Frank K. Moss, *Jour. Frank. Inst.*, **205**, 831, 1928.

The process of interpretation is greatly facilitated by a ready familiarity with the reservoir of fundamental or background knowledge of the science of seeing. Significant correlations, in some instances, have been found to exist between the results obtained by the use of widely varying experimental techniques. Several types of such correlations and an example of each follow:

Objective versus subjective measurements

Example: Influence of glare appraised by visibility measurements versus judgments of discomfort.[7]

Threshold data versus above threshold data

Example: Threshold speed of seeing [2] versus normal speed of reading.[1]

Specific criteria versus inclusive criteria

Example: Speed of reading versus nervous muscular tension developed incidental to reading.[5]

Such correlations often permit more general conclusions to be drawn from restricted researches than would be possible if the latter were analyzed independently.

EFFICIENCY, BEHAVIOR AND WELFARE.

It has been shown that the science of seeing is formulated from knowledge gained from measurements pertaining to visual perception, the visual apparatus, and human behavior and welfare. Such a science contributes to formal knowledge of the sensory processes, provides criteria for appraising conditions for seeing, and facilitates the development of adequate conditions for seeing. In the world of practice, *appraisal* of actual conditions for seeing and *improvement* of these are two objectives of the applied science of seeing. Although knowledge of the three complexities of seeing is applicable to each of these two purposes, the presentation may be simplified by emphasizing the major phases. The relative importance of research data for purposes of appraisal

[7] "Fundamentals of Glare and Visibility," L. L. Holladay, *Jour. Opt. Soc.*, 12, 271, 1926.

and improvement of conditions for seeing may be summarized as follows:

For appraising seeing conditions
Primary—Behavioristic data
Secondary—Visibility data

For improving seeing conditions
Primary—Visibility data
Secondary—Behavioristic data

Data upon which ophthalmology and optometry are based are omitted from this brief summary, even though they are an integral part of the science of seeing. Such a separation is more than an arbitrary one, if the basic data pertaining to human seeing-machines are obtained from, and applied to, subjects with normal vision. As already stated, ophthalmology and optometry are well developed sciences dealing with the visual tools.

There are at least four variables which determine the visibility of any object. Essentially, two of these are photometric, the brightness of the object and that of its background, respectively. The third is the size of the object; and the fourth is the time during which the image is stationary upon the retina. The relationships between these variables [2] are such that a deficiency in one may be compensated by an augmentation of one or more of the other three, provided *all* factors are above certain limiting values. These relationships have been determined for visual tasks which require the mere recognition of the presence of an object [8] and also for tasks in which details of the object must be perceived. The latter is a predominant characteristic of work-world visual tasks and requires visual conditions far superior to those required for the recognition of the presence of an object.

In general, the size of object or the contrast between the object and its background required for threshold seeing is approximately a logarithmic function of the brightness or intensity of illumination. This is in agreement with the general conclusion in sense-physiology that the sensation is

[8] "The Relation Between Field Brightness and Speed of Retinal Impression," P. W. Cobb, *Jour. Exper. Psych.*, 6, 138, 1923.

proportional to the logarithm of the stimulus. The influence of exposure-time upon the visibility of an object is small in comparison with the influence of size, contrast or brightness, when the time of exposure is limited to a range corresponding to the normal fixational pauses of the eyes. Visibility of small objects of high contrast with their backgrounds is influenced more by changes in size than by corresponding changes in contrast; and for relatively large objects of low contrast, the reverse is true.

An analysis [9] of the variability of the visual sense indicates that the brightness or intensity of illumination must be doubled in order to produce obvious and significant improvements in seeing. The coördination of this factor with the logarithmic relationship between brightness and visibility yields a footcandle scale of effectiveness designating about ten steps in a range from 0.5 footcandle to 500 footcandles, which represent equal steps in footcandle effectiveness.

Quality or spectral character of light is also important. Experimental evidence is available which indicates that visual acuity (ability of the eyes to perceive small details) increases as the light is restricted in spectral range.[10, 11] However, a refinement in spectral quality, which is accomplished at the expense of quantity of light, does not usually produce a significant improvement in visibility. In general, quality of light appears to be a factor secondary in importance to quantity of light, at least in the present era of low intensities indoors. An exception may be necessary in a situation which involves critical color-contrasts or for certain pathological conditions of the eyes.

These are the more prominent factors which influence visibility in a positive manner. They may be combined in countless ways and represent a range in visibility comparable to the difference between nearly-blind and normal eyes. Their effectiveness in regulating visibility is subject to reliable

[9] "Recommended Footcandles," M. Luckiesh and Frank K. Moss, *Trans. I. E. S.*, **26**, 1061, 1931.

[10] "The Effect on Visual Acuity of Shortening the Spectrum at the Blue End," M. Luckiesh and Frank K. Moss, *Jour. Opt. Soc. Am. and Rev. Sci. Inst.*, **10**, 275, 1925.

[11] "Visual Acuity and Sodium-Vapor Light," M. Luckiesh and Frank K. Moss, *Jour. Frank. Inst*, 1933.

quantitative appraisal. Another group of factors may be classified as negative factors, since their influence is in opposition to clear, quick and comfortable seeing.

Glare is perhaps the most prominent of the negative factors which decrease visibility. Light, which reaches the eyes direct from the light-source, may be termed preventable glare, since it may be eliminated. Light from the object and its immediate background is not usually considered as glare, although it does reduce visibility. It may be termed unpreventable glare.

Some of the more important facts which have been established may be summarized as follows:

The reduction in visibility by glare is a function of the intensity of illumination at the eye due to the glare-source.[12]

For a given light-source, the impairment of visibility is greater as the source approaches the line of vision.[12]

The visibility of large objects of low contrast with their backgrounds is decreased more by glare than small high-contrast objects.[12]

The sensation of discomfort due to a glare-source is a function of its intrinsic brightness as well as a function of the intensity of illumination, due to the glare-source, at the eyes.[12]

Glare produces definite and detrimental reactions in eye-muscles and in the nervous system, sometimes with serious and far-reaching results.[13]

A situation in which the eyes must look back and forth between relatively light and dark areas imposes a handicap upon the ease with which the eyes function.[14] It is probable that the deleterious influence of constant changes in pupillary

[12] "Glare and the Four Fundamental Factors in Vision," P. W. Cobb and Frank K. Moss, *Trans. I. E. S.*, **23**, 1104, 1928.

[13] "Muscular Tension Resulting from Glare," M. Luckiesh and Frank K. Moss, *Jour. Gen. Psych.*, 1933.

[14] "The Rate of Visual Work on Alternating Fields of Different Brightnesses," M. Luckiesh and Frank K. Moss, *Jour. Frank. Inst.*, **200**, 731, 1925.

and retinal adaptation is significantly greater than the beneficence of the brighter field. A somewhat different situation involves critical seeing within a bright area which is surrounded by a dark area. The influence of the dark surroundings, as appraised by visibility measurements, becomes negligible when the bright area subtends an angle of more than 30 degrees at the eyes.[15] If the eyes do not remain fixed within the brighter field, the ratio of brightnesses between the brighter field and the surroundings may be of the order of 10 to 1 without significantly deleterious effects.[2] It might be stated that the adaptive processes are adequate for natural outdoor environments, but are inadequate to compensate for some of these abuses imposed by artificial environments.

The preceding discussion presents a few of the salient features of the realm of visual perception or visibility which are useful in developing better conditions for seeing. Likewise, salient conclusions deduced from the realm of human behavior and welfare will be presented briefly.

The measurement of nervous muscular tension [5] is at present the most successful criterion for the invasion of the internal realm, as represented by the upper curve of Fig. 1. It is obvious that the effect of fatigue may be indicated by the decrease in production of useful work, if the subjects approach exhaustion in the performance of the task. For usual tasks such a decrease in production is not always obtained, and in many cases there is even an increase in production as mild fatigue is developed.[16] Nervous tension and fatigue commonly cause a tightening of certain muscles and represent an expenditure of human energy which does not produce useful work.

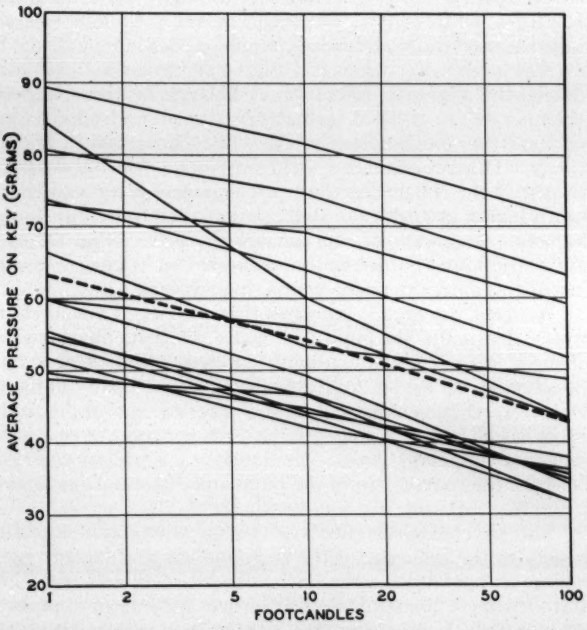
These effects of poor seeing conditions are obvious in driving an automobile at night on a poorly illuminated street and under other conditions, such as in fog or rain, when visibility is low. A boxer is fatigued by nervous muscular tension due to being on the alert visually and mentally, as

[15] "The Effect of Dark Surroundings Upon Vision," P. W. Cobb and Frank K. Moss, *Jour. Frank. Inst.*, **206**, 827, 1928.

[16] "Lighting Plus Vision Equals Seeing," M. Luckiesh and Frank K. Moss, *Trans. I. E. S.*, **25**, 807, 1930.

well as muscularly. Everyone can muster other examples from personal experience. In a research involving reading a book of excellent typography, nervous muscular tension was appraised by the increase in pressure unknowingly exerted by fingers of the left-hand resting upon a key. As the intensity

FIG. 3.



Showing the decrease in nervous muscular tension resulting from increases in level of illumination when reading a book of excellent paper and printing. The thin solid lines represent the individual results obtained from 14 subjects. The heavy broken line represents the average of the individual results.

of illumination increased from 1 to 100 footcandles, the nervous muscular tension definitely decreased for each of the 14 subjects, as shown in Fig. 3. Incidentally, the reading could readily be done under an intensity of one footcandle, but this research throws some light upon ease of reading.

These results indicate that the benefit of better seeing conditions, produced by higher levels of illumination, extended far beyond the level of illumination at which production of work generally ceases to increase appreciably. It has also been shown [5] that the elimination of preventable glare likewise decreases nervous muscular tension.

Inexperience with adequate levels of artificial illumination has led some to believe that higher levels of illumination are injurious and cause additional fatigue. Measurements of the extremely delicate balance of the ocular muscles [17] failed to detect the slightest difference in balance of these muscles when an exacting visual task was performed under intensities of 5 and 100 footcandles (on the white background), respectively. Other researches [18] yield ample experimental evidence to justify the conclusion that retinal fatigue is not caused by much higher intensities of illumination than those now found indoors. Furthermore, one can scarcely believe that the eyes are not adapted to the enormously greater brightnesses and intensities outdoors under which they evolved.

A recent research [19] indicates that prolonged visual effort causes dilation of the pupil and, hence, suggests physiological changes in the eyes, which may represent ocular fatigue and possibly serve as an indicator for general bodily fatigue. However, these changes in pupil size do not appreciably effect visual acuity,[20] since the latter is constant over a wide range of pupillary sizes. Obviously, a correlation exists between the contraction of the pupil and discomfort produced by glare.

The psychological effects of visual stimulation are due largely to the influence of the surroundings and include such factors as confidence, stimulation, impression, concentration and attitude. Some of these influences have been appraised by quantitative measurements. It has been found that visual

[17] "Eye-Fatigue and Its Relation to Light and Work," P. W. Cobb and Frank K. Moss, *Jour. Frank. Inst.*, **200**, 239, 1925.

[18] "Analysis of the Literature Concerning the Dependency of Visual Functions Upon Illumination Intensity," L. T. Troland, *Trans. I. E. S.*, **26**, 107, 1931.

[19] "Size of Pupil as a Possible Index of Ocular Fatigue," M. Luckiesh and Frank K. Moss, *Amer. Jour. of Ophthal.*, **16**, 1933.

[20] "Influence of Pupillary Diameter on Visual Acuity," P. W. Cobb, *Amer. Jour. Phys.*, **36**, 335, 1915.

tasks are performed at a slower rate amid noisy surroundings than in a quiet environment.[2] Tasks which are performed entirely by the sense of touch may be performed faster when the visual sense is stimulated.[21] These are examples from the vast unexplored domain of the psychological aspects of seeing. Besides the psychological complexities of perception, which directly influence behavior, there are many other phases which are at least of secondary importance.

It is not now possible to present data which are representative of the complete influence of better seeing conditions upon human welfare. Obviously, such data involve the life-span of the individual. Statistical records of large groups should be kept and analyzed by eye-specialists having them under supervision for years. It has been shown that the improvement in conditions for seeing, under which critical visual tasks were performed for a few months, resulted in a semi-permanent benefit to the eyes.[22] The prevalence of defective vision indicates a need for additional research in this phase of the science of seeing.

IMPROVING SEEING CONDITIONS.

A detailed discussion of the controllable factors that contribute improvements in seeing conditions is beyond the scope of this outline of the new science of seeing. Many of these factors have been mentioned in foregoing paragraphs. Eye-glasses which "sharpen" the visual tools are prominent controllable factors in the numerous cases of defective eyes. Many persons who need glasses are without them, owing to pride, indifference or ignorance. Eye-specialists already serve well in supplying corrective glasses.

Light is always a factor in seeing. Intensities of illumination are apparently woefully inadequate throughout the artificial world. Usually, anyone can easily increase the quantity of light, and thereby improve seeing, by increasing the wattage of the electric lamps. Although lighting specialists exist, they are much more concerned with supplying light than lighting. The latter involves direction and distribution.

[21] "The Dynamogenic Influence of Light Upon Tactile Discrimination," H. M. Johnson, *Psychogiology*, **2**, 351, 1920.

[22] "Studies in Illumination," U. S. Public Health Bulletin, No. 181.

It is neither difficult nor costly to obtain adequate quantities of light and proper lighting by adding to the prevalent general-lighting systems localized light properly directed upon the visual task. The general light satisfies general requirements and improves seeing by decreasing the contrast between the work and the general surroundings. The localized light provides lighting for the specific visual task. By properly locating the local light-source advantages of highlights and shadows are obtained.

Proper backgrounds can be supplied where few exist today. These may be white, black, gray, or colored, depending upon the visual task.

Anyone making things to be seen, such as printing, signs, signals, etc., is in a position to apply the science of seeing.

Everywhere in a half-seeing world, where seeing is almost as important as living and where the efficiency, behavior and welfare of human beings is so dependent upon seeing, there are opportunities to aid the human seeing-machine.

Finally, the most important factor in the improvement of seeing conditions is a seeing-consciousness on the part of every owner of eyes. Such a consciousness can scarcely be said to exist. In the educational activities of eye professions, medical associations, social science, insurance companies, health agencies, optical manufacturers, lighting interests, safety councils, and many other groups, the development of a seeing-consciousness may well be a major objective. Certainly, no greater contribution to human welfare can be made than by awakening public consciousness to the widespread abuse of eyes and to the cost and value of seeing.

AIR CONDITIONING FOR COMFORT AND HEALTH, PAST—PRESENT—FUTURE.*

BY

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What is air conditioning? More particularly, what is meant by air conditioning for comfort and health? Why is air conditioning fast becoming a topic for general conversation? Why are the technical and popular press publishing numerous articles on various phases of the subject? Is air conditioning really a new industry whose increasing momentum will carry us out of present economic difficulties and on to the high road of prosperity, or is it just a passing fad?

This paper aims to answer these and other questions by presenting in readily understandable form, a brief summary of the art of air conditioning and certain conservative predictions for the future. Neither fanciful theories nor astounding new discoveries are contained herein. Proven facts and accepted procedure will be discussed in a manner which it is hoped will promote a broad and accurate understanding of the basic principles and practice in the field of conditioning air.

AIR CONDITIONING IN THE PAST.

Conditioning air for comfort and health is both an old and a new art; old, because its beginning dates back to the days when slaves fanned their masters with palm leaves and new, because even today no one has produced mechanically the delightful and invigorating effect of Mother Nature's perfect air conditions on a spring morning in the open country.

Human beings have always been susceptible to the condition of the air in which they live. Probably the first instance of any attempt at air conditioning was the discovery

* Presented at a meeting held Thursday, January 26, 1933.

by some prehistoric man that the fire, caused by lightning striking a nearby tree, would warm him on cold nights and make him more comfortable. Since that time and almost up to the present day, man's principal interest in air conditions has been to *raise* the air temperature where necessary to improve comfort and health.

The early Romans are said to have developed a chamber containing a fire beneath their homes, presumably to warm the floor. Then came the fireplace which was almost universally used in homes for centuries. It remained for none other than Benjamin Franklin himself to perceive the gross inefficiency of the fireplace and to perfect the iron stove for burning wood, about the middle of the eighteenth century. Figure 1 shows several types of the Franklin stove, and, crude as they were, they represented a distinct advance in the art of heating.

The following advertisement, which appeared in the *Philadelphia Evening Journal* for June 1, 1859, may be of interest:

KAHNWEILER'S PATENT VENTILATING ROCKING CHAIR.—This is a novelty that commends itself to all who value health and comfort. The invalid will recognize it as an invention especially conducive to his well being, inasmuch as with the addition of, say two cents worth of ice per day, the luxury of pure cool air may be fully enjoyed within doors, and the heat of summer, or the vitiated atmosphere of a closed apartment, defied. Sold at the Manufacturer's Depot, Masonic Hall, No. 715 Chestnut Street, by

JAMES WILCOX.

Writing, nearly one hundred years ago, in his book entitled "The Art of Warming and Ventilating," one Walter Berman said:

"Warmth exerts a considerable influence on our physical, if not also on our mental condition. Hence the formation and regulation of artificial climate will assume the character of an art for developing and expanding the mind and the body, for preserving health and prolonging life."

The development of a complete heating system, so ably begun by Franklin, was taken up where he left off, and the results today are the modern warm air heating systems and the various forms of radiation systems.

While much attention has been given to the raising of air temperature in cold weather, it is only recently that the

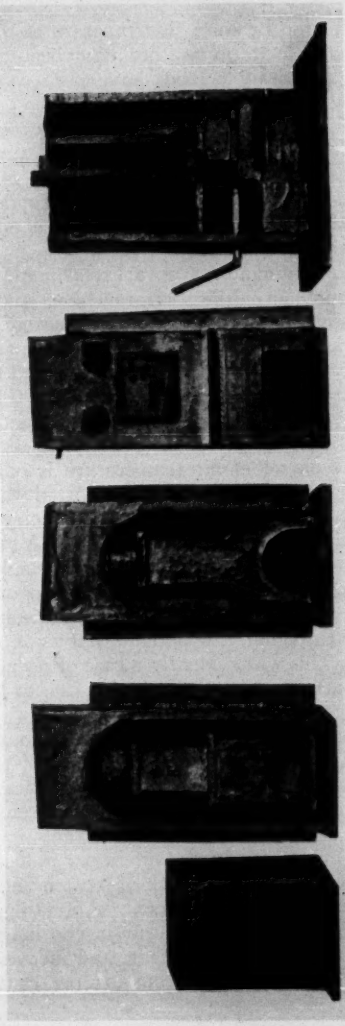


FIG. 1.

Models of stoves invented by Benjamin Franklin.

opportunities for lowering air temperatures to improve comfort and health in warm weather, have been recognized.

Although perishable foods have been cooled by natural ice or snow for centuries and ice was first delivered to a home in this country, for such a purpose, in 1802, the principle of mechanical refrigeration was not discovered until 1824. In that year, the great Faraday, father of our electrical science, noticed that ammonia vapors, condensed by compressing and cooling, suddenly began to boil and became very cold when the pressure was removed.

In 1860, Ferdinand Carré, a Frenchman, made the first practical ammonia absorption machine, and in 1877 the first successfully refrigerated railway cars were placed in year-round service. Today, the amount of manufactured ice greatly exceeds the natural ice harvested, and the mechanical refrigeration art, which has brought about this condition, is available for the improving of air conditions during the hot, uncomfortable summer months.

But the control of air temperature is only part of the story of air conditioning. It is reported that on Friday, December 2, 1848, the steamer "Londonderry" left port for Liverpool with 200 emigrant passengers. A storm arose and the passengers were ordered into a very small cabin, which was hatched in, with a tarpaulin fastened over the hatch. Some time later, when one of the imprisoned passengers broke out of the cabin, it was found that 72 of the 200 persons were dead. This was evidently a case of poor ventilation, or to be more accurate, heat prostration due to the increase of temperature and humidity.

About one hundred and fifty years ago, Lavoisier, the great chemist, concluded that an excess of carbon dioxide was the cause of asphyxiation in badly ventilated enclosures.

About the middle of the nineteenth century, a noted physiologist named Claude Bernard wrote:

"The ill effects of vitiated air in our indoor atmospheres are due undoubtedly to the lack of oxygen and the excess of carbon dioxide, since every person, in breathing, reduces the natural oxygen content of the air in the lungs from about 21 per cent. to about 17 per cent. and increases the carbon dioxide content of this air from .03 per cent. to about 4 per cent."

Some thirty years later, the views of Brown-Sequard and D'Arsonval were generally accepted, as follows:

"The ill effects of vitiated air are due not to a lack of oxygen or an excess of carbon dioxide, but to a poison in the expired breath which literally causes 'crowd poisoning.'"

Today, it has been proven that a reduction of oxygen content in the air to something below 15 per cent. is necessary to produce disturbing symptoms, and even in our most crowded rooms, the oxygen percentage rarely drops below 20 per cent. Furthermore, a carbon dioxide percentage of 3 per cent. or more is required to produce disturbing symptoms and in our most crowded rooms it is rare to find the carbon dioxide content rise higher than ½ per cent. Therefore, oxygen and carbon dioxide have very little to do with the ill effect of vitiated air. Still further, animals have been inoculated with 15 to 20 c.c. of fluid condensed from the breath of a person exhaling for an hour into a condenser. This inoculation produced no harmful effects upon the animals, thereby exploding the theory that the exhalations of a normal person contain poison.

In the light of all present knowledge, it seems reasonable to conclude, therefore, that the ill effects of vitiated air are the result of heat stagnation in the body. The term "heat stagnation" refers to a condition wherein the heat regulating mechanism of the body breaks down and fails to properly control body temperature. This heat stagnation is due to air of improper temperature, humidity, or velocity, the resultant symptoms being headache, dizziness, nausea, oppression or even total collapse.

As a demonstration of the validity of this conclusion, experiments were carried on at the Institute of Hygiene in Breslau, where normal persons were kept in an air-tight compartment of about 3 cubic meters capacity, for periods of time up to four hours. As long as the temperature and humidity were low, no discomfort was noticed by these persons, even with the carbon dioxide content of the air over 1 per cent. With the temperature and humidity allowed to climb, disturbing symptoms were noticed promptly. At 80° F., with a relative humidity of about 60 per cent., or at 75° F., with a relative humidity of about 90 per cent., practically all persons began

to show depression, dizziness, headache and nausea. When these persons were allowed to breathe fresh air from the outside, through a tube, this air being raised to the temperature and relative humidity of that within the compartment, it gave no relief. Furthermore, the air from the compartment did not produce disturbing symptoms to the persons outside the cabinet when breathed through a tube. However, the unfavorable symptoms experienced by the persons within the cabinet could be almost immediately relieved by either drying the air in the cabinet or by cooling it or by putting it in rapid motion by means of a fan, without any chemical change in the air itself.

In concluding this brief historical sketch on the art of air conditioning, the history of railway car air conditioning is interesting and pertinent.

The first recorded attempt to air condition a railway car is said to have been made in 1857, when the Erie Railroad installed equipment in a car to wash and humidify the air in winter and cool it, by evaporation, in summer. The project was abandoned because of the lack of properly developed apparatus.

It is reported that evaporation cooling has been used in India since about 1890. Railway car air conditioning was undertaken by the Baltimore and Ohio Railroad about 1918, under the direction of their chief electrical engineer. Further experiments were carried on in the middle west during 1924, by the Atchison, Topeka and Santa Fé Railway. Complete control of the four essential elements of air conditioning was applied to the 74-ton steel car, No. 5275, on the B. and O. R.R., July 1, 1929, and, in April, 1930, this railroad placed in service a mechanically operated, completely air conditioned dining car, the *Martha Washington*. In May, 1931, this same railroad ran the first completely air conditioned train, the *Columbian*, between New York and Washington. The greatest advances in this field have been made in the last few years and, during this last summer, at least seven railroads had air conditioned cars or trains in full operation.

AIR CONDITIONING AT PRESENT.

It is now in order to consider, in as much detail as is permitted by the scope of this paper, the theory and practice of air conditioning as it exists today.

Generally speaking, the importance of air conditioning from the standpoint of comfort and health is well recognized and certain of the basic theories are established. It is not the intent of this paper to discuss the recognized success of air conditioning as applied to industrial processes where, in the manufacture of certain hygroscopic materials, it becomes necessary to control the condition of the air in which the manufacture is carried on.

The importance of air conditioning might easily be recognized, since the average man's daily menu consists of about 3.5 lbs. of food, 4 lbs. of water, and 34 lbs. of air. Chemical authorities indicate that a substantial portion of man's energy comes directly from the air he breathes.

From the standpoint of health and comfort, the art of air conditioning may be considered in two divisions. First, it is necessary to establish standardized air conditions which are best suited to the physiological requirements of the human body. With these standards determined, the problem is then to develop and place within the reach of all, apparatus to produce and maintain these standard conditions.

PHYSIOLOGICAL REQUIREMENTS.

Considering the physiology of the human body, it should be remembered that body temperature is the resultant of two factors—heat production and heat loss. Heat production is the direct result of the chemical combustion of food within the body. Heat loss is the direct result of heat dissipation from the lungs and skin. For normally healthy persons, the body temperature is maintained at 98.6° F., by reason of the balance between heat production and heat loss, this heat balance occurring automatically and varying but slightly with wide changes in external air conditions.

The heat losses from the body depend upon a number of factors, such as the degree of physical activity, the air temperature, relative humidity, air motion, amount of clothing worn and age of person. The following table indicates the

approximate allocation of this heat loss for a normally clothed person seated at rest, in an atmosphere of about 70° F.:

TABLE 1.

Heat Loss from a Normally Clothed Person Seated at Rest in an Atmosphere of about 70° F.

Radiation, conduction and convection	73.0%
Evaporation from the skin	14.5%
Evaporation from the lungs	7.2%
Warming inhaled air	3.5%
Warming ingested food	1.8%
Total	100%

These percentages vary considerably with variations in air temperature and physical activity although they seem to be practically independent of the relative humidity of the air at normal temperatures.

As indicated above, the body is simply a power plant. It takes in food with a definite heat content, converts part of it into work, stores some in the internal organs and dissipates the rest as heat, this dissipation occurring about as indicated in Table 1. Following the power plant analogy further, the alimentary canal, where the fuel is fed to the body, may be compared to the stoker or fuel pulverizer. The tissues which chemically burn the food may be compared to the furnace or combustion chamber. The blood which carries the waste heat to the skin for distribution is analogous to the ventilating system in the boiler room; and the muscles of the body correspond to the prime mover.

The following table is interesting because it indicates the wide variation of total heat dissipated from the body, with varying degrees of physical activity:

TABLE 2.

Total Heat Loss from a Normal Person with Varying Degrees of Physical Activity.

Seated at rest	384 B.t.u. per hour
Standing at rest	431 B.t.u. per hour
Walking 2 miles per hour	761 B.t.u. per hour
Walking 3 miles per hour	1049 B.t.u. per hour
Walking 4 miles per hour	1388 B.t.u. per hour
Walking 5 miles per hour	2530 B.t.u. per hour
Slow run	2285 B.t.u. per hour
Very severe exercise	2555 B.t.u. per hour
Maximum exercise	3333 to 4726 B.t.u. per hour

In ordinary air conditioning calculations, for homes, theaters, offices, etc., the heat dissipated into the air by each occupant is usually taken as 400 B.t.u. per hour, although the above table shows that this figure may vary by a ratio of more than 10 to 1, depending upon the degree of physical activity.

Since under ordinary conditions, the body temperature is maintained at its normal level, 98.6° F., the heat production must equal this heat loss. In normal persons, heat production is controlled by the heat regulating mechanism of the body. This mechanism can adjust itself if air conditions are held within certain limits, but under adverse conditions, the heat regulating mechanism of the body fails and serious physical damage may occur.

While the heat dissipated from the body seems to be independent of the relative humidity over a wide range, this is not true of bodily comfort. Probably this is because bodily perspiration increases with increased humidity and without any compensating change in the evaporation of moisture from the skin. Table 3 shows data in connection with sensible perspiration as related to temperature and humidity.

TABLE 3.

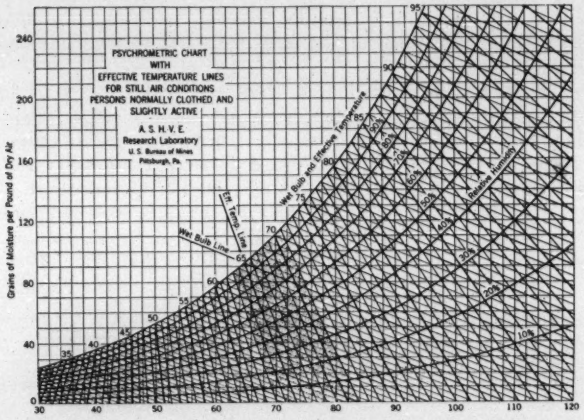
Condition of Sensible Perspiration for Persons Seated at Rest for Various Atmospheric Conditions. (40 per cent. of subjects registered degree of perspiration equal to or greater than indicated.)

Degree of Perspiration.	Atmospheric Condition.					
	95 Per Cent. Relative Humidity.			20 Per Cent. Relative Humidity.		
	E.T.*	D.B.	W.B.	E.T.	D.B.	W.B.
Forehead clammy	73	73.6	72.4	75	87.0	60.7
Body clammy	73	73.6	72.4	75	87.0	60.7
Body damp	79	79.7	78.4	81	97.5	67.5
Beads on forehead	80	80.8	79.4	87	109.4	75.2
Body wet	84.5	85.4	84.0	86.5	108.5	74.6
Perspiration on forehead runs and drips	88.0	89.0	87.6	94.0	125.2	85.4
Perspiration runs down body	88.5	89.5	88.1	90.0	116.0	79.5

* E.T. = Effective temperature (see following paragraphs).

The American Society of Heating and Ventilating Engineers has investigated the combined conditions of temperature, humidity and air motion in which a person feels comfortable. No single comfort standard can be laid down which will meet the needs of every individual. However, several standards are given, in workable form, on the A.S.H.V.E. Chart of Effective Temperatures, with comfort zones superimposed (see Fig. 2).

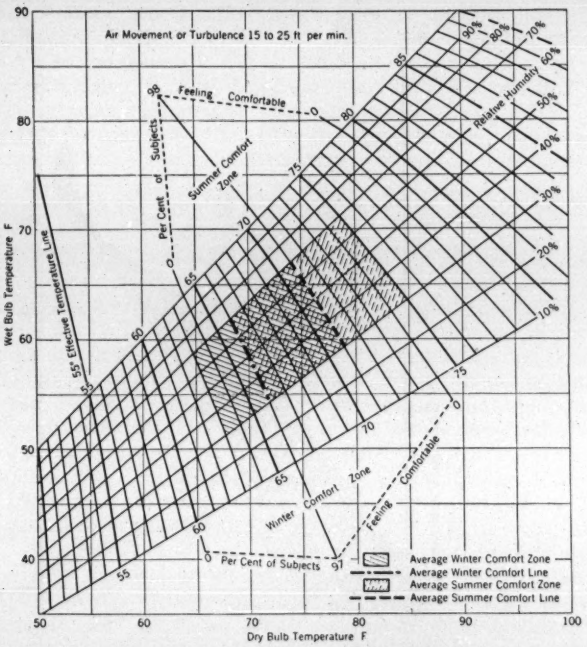
FIG. 2.



Psychrometric Chart (A S H.V.E.).

In considering this chart, it is necessary to understand the meaning of 'effective temperature.' "Effective temperature may be defined as an arbitrary index of the degree of warmth or cold felt by the human body in response to temperature, humidity and movement of air." Effective temperature is not a temperature at all, in the usual sense, but is an index defining temperature, humidity and air motion. Experiments have shown that this composite index indicates the physiological effects produced in the body by heat or cold, regardless of the temperature, humidity and air movement components.

FIG. 3.

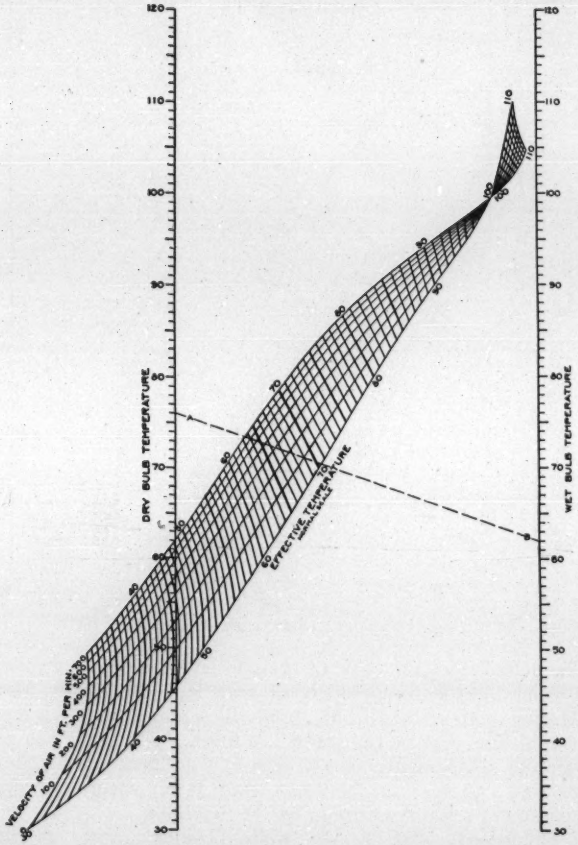


Comfort chart showing summer and winter comfort zones.

The actual numeric value of the effective temperature index is fixed by the temperature of saturated air which, at a velocity of about 20 F.P.M., produces a sensation of warmth or cold like that of the given condition. Thus, air has an effective temperature of 65° when it induces a sensation similar to that of air at about 20 F.P.M., saturated with moisture at a temperature of 65° F. dry bulb.

Considering Fig. 2, the winter comfort zone, as determined at the A.S.H.V.E. Laboratory, ranges from 63° to 71° E.T. While at rest, 97 per cent. of the experimental subjects were found to be comfortable at 66° E.T. and this

FIG. 4.



Curves showing influence of air movement on effective temperature.

temperature was accepted as the winter comfort line, or optimum effective temperature. The summer comfort zone for men and women in the United States, wearing customary warm weather clothing, runs from about 67 to 75 degrees E.T., the probable optimum effective temperature being 71° E.T. Figure 3 depicts the shift of the comfort zone due to seasonal variations. The optimum effective temperature in summer is about 5° higher than in winter due probably to seasonal variation in the clothing worn, and to certain bodily adaptation to seasonal weather changes.

Data are available for converting the effective temperature of air conditions at other than the standard 15–25 F.P.M. velocity, as shown in Fig. 4. In using these charts, it should be borne in mind that they apply only to average, normally healthy persons, adapted to American conditions and they are only applicable between relative humidities of 30 per cent. to 70 per cent. Still further, they apply to rooms heated by the usual American convection methods. They do not apply to rooms heated by radiant methods, such as the British panel system, open fireplaces, etc. Still further, they do not apply to persons doing medium or heavy muscular work in still air.

In artificially cooled enclosures, the contrast between outdoor and indoor air conditions becomes an important factor in regard to temperature and humidity to be maintained. The practical application of air conditioning in warm weather does not reduce the temperature to the optimum effective value. It does aim to maintain an effective temperature temporarily comfortable to the persons therein, at the same time avoiding sensations of chill when entering the building and intense heat when leaving it. For exposure of three hours or less, desirable temperatures are indicated by Table 4.

Thus far in considering the combined effect of temperature, humidity and air movement, no mention has been made of atmospheric pollution. Dusts, toxic gases and other foreign matter may frequently be present in the atmosphere in undesirable quantities, thus bringing in air purity as the fourth necessary factor for complete air conditioning. In other words, the air should be free from dusts, bacteria and

TABLE 4.

Desirable Indoor Air Conditions in Summer Corresponding to Outdoor Temperatures.
Applicable to Exposures Less Than 3 Hours.

Outdoor Temp. (Deg. Fahr.)	Indoor Air Conditions with Dew-Point Constant at 57° F.		
Dry-Bulb.	Dry-Bulb.	Wet-Bulb.	Effective Temperature.
95	80.0	65.0	73.4
90	78.0	64.5	72.2
85	76.5	64.0	71.1
80	75.0	63.5	70.2
75	73.5	63.0	69.3
70	72.0	62.5	68.2

odors, many of which are capable of producing profound pathologic effects, as well as damage to property and vegetation.

Physicians indicate that the general air pollution in many industrial cities provokes pulmonary diseases and under certain circumstances, may even lead to cancer, through some underlying cause which, apparently, is not fully understood. The constant inhalation of solid and gaseous ingredients, such as carbon, silica, sulphur dioxide, etc., often present in city air, irritates the mucous membranes of the nose, throat and lungs, producing discomfort and in some instances injuring health. Apparently smoke is not directly poisonous although it may have some influence on acute lung diseases. In addition, hay fever and other diseases caused by air borne pollen are excellent illustrations of the possible harmful effects of suspended solid matter of a specific nature.

In concluding this brief study of the physiological requirements and standards for air conditioning, it seems that the following is an adequate definition: "Air Conditioning is the simultaneous control of temperature, humidity, air movement and purity, to produce the optimum condition for physical comfort and health."

Later on in this paper, it will be explained that probably there are one or more other elements to be controlled, but in the present state of the art, this definition is satisfactory.

APPARATUS FOR AIR CONDITIONING.

Having specified certain standard air conditions, it is now in order to consider, in a general way, the apparatus available at the present time to produce these conditions, together with comments regarding the operating characteristics of such apparatus. For the sake of clarity, this consideration will be sub-divided into the four groups of apparatus designed to control the four elements of air conditioning, as defined above. It will be understood that system combinations are possible, whereby one unified system, made up of the various elements which are discussed, will offer the specified simultaneous control throughout the entire year.

CONTROL OF TEMPERATURE.

Before considering the actual apparatus for the control of temperature, it seems advisable to review, briefly, a few of the well-known fundamentals of heat transfer.

The Universe is composed of matter and energy. Matter is that which possesses mass and inertia. According to the well-known law of conservation of matter, it may be changed as to form or state but it can neither be created nor destroyed. All matter contains energy, in one form or another, and energy may be defined as the capacity for doing work, or the ability to overcome resistance. It also can be changed as to form but it can neither be created nor destroyed.

Heat is a form of energy and like other forms of energy, may be measured in various units, although the one most commonly used in air conditioning work is the British Thermal Unit, or B.t.u. This unit is defined as the heat energy required to raise a pound of water from 63° to 64° F. Temperature, as is well known, is an arbitrary scale of measurement, indicating the ability of a body to give off or absorb heat. Heat and temperature cannot be used interchangeably, although the magnitude of the temperature *change* of a body is directly proportional to the heat lost or gained during that change. The Fahrenheit scale of temperature is used exclusively in air conditioning work, in this country.

All matter has the ability to absorb and transfer heat although the extent of this ability varies with the material and its thermal condition. Heat is transferred in three ways:

a. By radiation.
b. By conduction.
c. By convection.

All matter is considered to be made up of countless small particles called molecules which are supposed to be in a violent state of vibration, these vibrations setting up waves which travel at the speed of light, or 186,000 miles per second. When these waves strike other particles of matter, a corresponding vibration is set up in the second body. The transfer of heat by radiation obeys the laws of light transfer. In other words, radiant heat may be reflected, refracted and absorbed. The transfer of heat from the sun to the earth is the best example of heat transfer by radiation.

Heat will pass or flow from one body to another body in contact with it, in the direction of lower temperature or from the higher to the lower state of heat intensity. For example, when one end of an iron bar is heated in a flame, the flow of heat takes place from the hot end to the cold end. This is an example of heat transfer by conduction, the rate of this transfer depending on the difference in temperature between the hot and the cold ends and the characteristics and dimensions of material making up the conduction path. Where rapid and effective heat transfer is desired, materials having a high heat conductivity, such as copper and other metals should be used. Where a nonconducting or heat insulating condition must be set up, materials having low heat conductivity, such as asbestos or magnesia, are used.

Where heat is transferred by convection, the heat energy is conveyed from one point to another by a fluid, such as air, water or oil by the motion of the fluid as such, this convection being natural or forced, as determined by the design of the apparatus. The transfer of heat from a boiler to a hot water radiator in an ordinary gravity hot water heating system is a good example of natural convection. If a circulating pump is added to this heating system, the result is heat transfer by forced convection.

In considering the apparatus for the control of temperature as a part of air conditioning, it is recognized that in the winter time the air temperature must be raised and in the

summer time the air temperature must be lowered to produce the optimum condition. Therefore, the consideration must again be sub-divided into heating systems and cooling systems.

HEATING SYSTEMS.

The fundamentals of present accepted heating systems are well established, and it is not the intent of this paper to go into them in detail. They may be briefly summarized as follows:

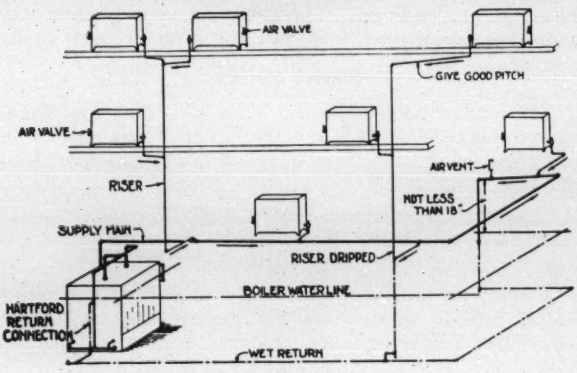
a. Warm air heating systems.
b. Steam radiation systems.
c. Hot water radiation systems.

A warm air heating system constitutes the oldest form of central heating system now in general use. It consists essentially of a combustion chamber, generating the heat energy, surrounded by circulating air which transfers this heat energy from the combustion chamber to the room, by means of either natural or forced air movement. Where natural circulation in the warm air system is properly laid out, adequate heat transfer is obtained, with little or no adverse effect from variable atmospheric conditions. However, the entire system lay-out must be done rather exactly to accomplish this result, and certain deficiencies in a warm air system lay-out can be overcome by means of forced circulation of the air. This explains the rapidly growing trend toward forced warm air systems, using a blower of adequate air delivery characteristics.

In recent years, there has been a definite trend away from warm air systems, but the advent of complete Air Conditioning at a central point in the home, with duct transfer of the conditioned air, has given a new impetus to the warm air system, and it probably represents the ultimate form of heating for homes.

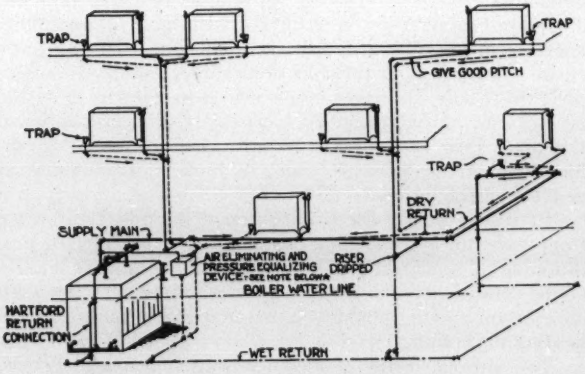
The various forms of steam radiation heating systems, both low and high pressure, one pipe and two pipe, wet and dry return, etc., are well understood by those in heating circles and will only be briefly mentioned here. A one pipe, gravity return steam heating system, using vacuum valves, represents a relatively low cost form of steam radiation heating which will give generally satisfactory results, in

FIG. 5.



Gravity one-pipe steam heating system.

FIG. 6.



Vapor system of steam heating.

homes. Some of the details of such a system are shown in Fig. 5. In an effort to improve the operation of gravity steam systems (where the steam flows under the action of boiler pressure, and the condensate returns directly to the

boiler by gravity), there have been devised various types of thermostatic traps and modulating inlet valves for radiators, as well as devices to insure positive return of condensate to the boiler. Systems so equipped are commonly designated as "vapor" systems. The many modifications embodied in vapor systems offer some small increase in efficiency for the increased cost, and they provide improved distribution, particularly in larger buildings where a simple system cannot be applied. The elements of a vapor system are shown in Fig. 6.

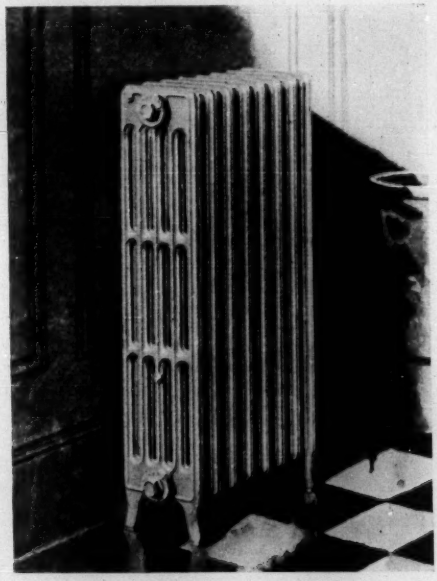
There is a definite trend toward radiation of improved appearance which, at the same time, gives a lower temperature difference between floor and ceiling and therefore a reduced heat loss from the home for a given degree of comfort. An excellent example of this type of radiation is the baseboard radiator (applicable to both steam and hot water), installed along the floor line and concealed behind attractive grille work. Figure 7 shows a modern cast iron radiator and Fig. 8 a concealed radiator of pleasing appearance.

Going one step further, if forced circulation of air from concealed radiation is employed, using a motor-driven fan, still further reduction in the temperature difference between floor and ceiling can be obtained, with a consequent additional saving in operating cost and improvement in comfort. These forced convection radiators are commonly known as unit heaters. They have received wide application in the heating of large spaces and the advantages of concealment, effective heat distribution and unit temperature control may eventually give them wide acceptance in the heating of homes and other smaller enclosures.

Hot water heating systems are used much more universally abroad than in this country, principally because of the low temperature radiating surface which prevents the burning of dust on the surface to create odors. A properly laid out gravity hot water heating system in a home will give adequate heat distribution to the various radiators. However, as with warm air systems, this requires rather exact knowledge in making the piping lay-out. To overcome deficiencies in this respect and also to speed up the response of a gravity hot water heating system, which is naturally

sluggish, there is a definite trend toward the forced circulation of the water by means of a circulator, even in small homes. Hot water heating systems are particularly suitable to large buildings where complete air conditioning is to be provided. They may be so zoned that the water heads are kept within safe limits, the water making an excellent transfer medium

FIG. 7.



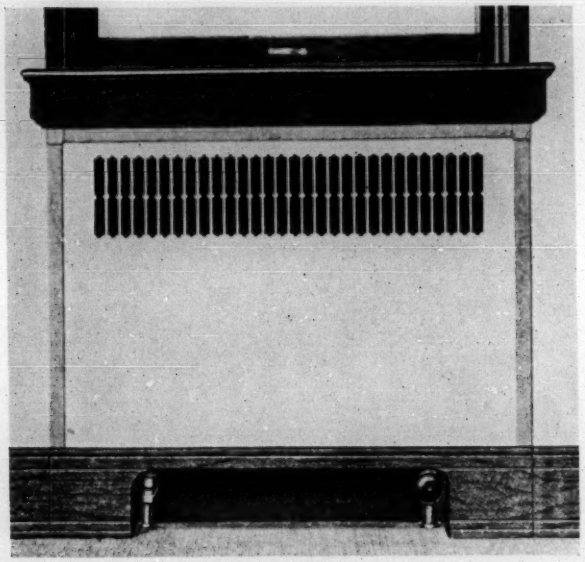
Modern style radiator.

for heating in cold weather and cooling in warm weather. A very large office building in New York City has just been completed, using such a system.

Considerable attention has been given to the recent developments in panel heating, used rather extensively in Great Britain. This system utilizes large panels built in as

part of the wall construction, operating between 100° F. and 150° F., to heat the occupants of the room almost entirely by radiant heat transfer. It is claimed that such a heating system permits lower air temperatures in the room for a given degree of comfort. This is evidently true but a recent study indicates that the increased first cost of panel heating,

FIG. 8.



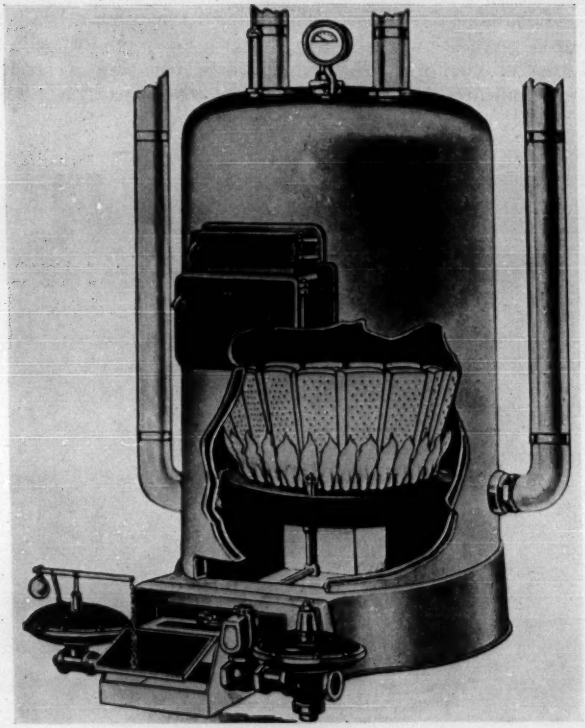
Typical concealed radiator.

adequate to meet accepted standards in this country, is not justified by operating economies or improved comfort.

In considering heating systems the characteristics of the various fuels available should be mentioned.

Electric energy, rather obviously, meets all the require-

FIG. 9.



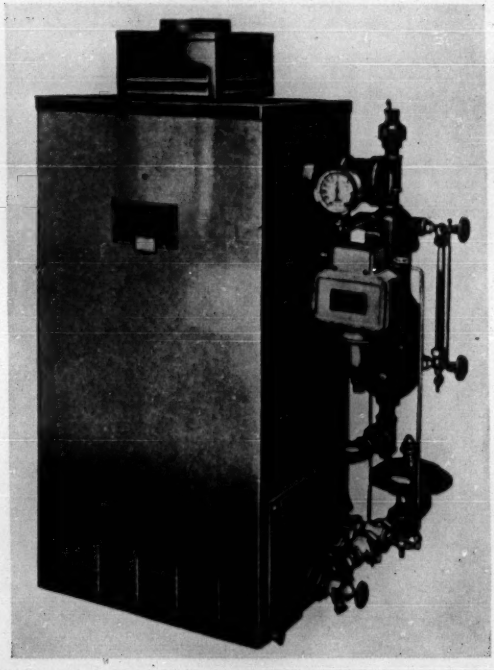
Modern conversion gas burner.

ments of an ideal heating medium, except that of cost. Even with off-peak power rates available, there are only a few favored localities in the United States, where the base heating load can be supplied economically with electric energy.

Gas is available in most population centers as a heating

medium. Effective combustion of gas is readily obtained, and it possesses all the attributes of the ideal fuel, except those of personal hazard and relatively high operating cost. The personal hazard can be largely eliminated with adequate

FIG. 10.



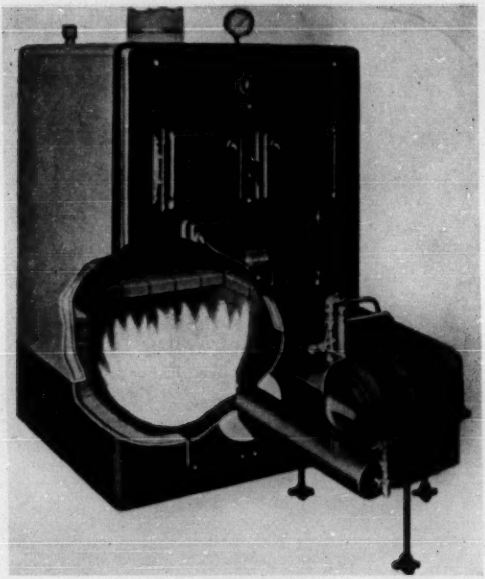
Modern gas boiler.

control systems and the cost trend of manufactured gas is downward, although with less rapidity, perhaps, than would justify its more widespread use. Natural gas, where available at reasonable cost, is of course an excellent fuel. Figure 9

shows a typical conversion gas burner and Fig. 10 a modern gas burner-boiler unit.

Oil is about comparable to gas as a clean and efficient fuel except that the operating cost at present rates, is usually substantially lower and the problem of effective combustion requires more consideration. It can be stored with less waste-

FIG. 11.



Modern conversion oil burner.

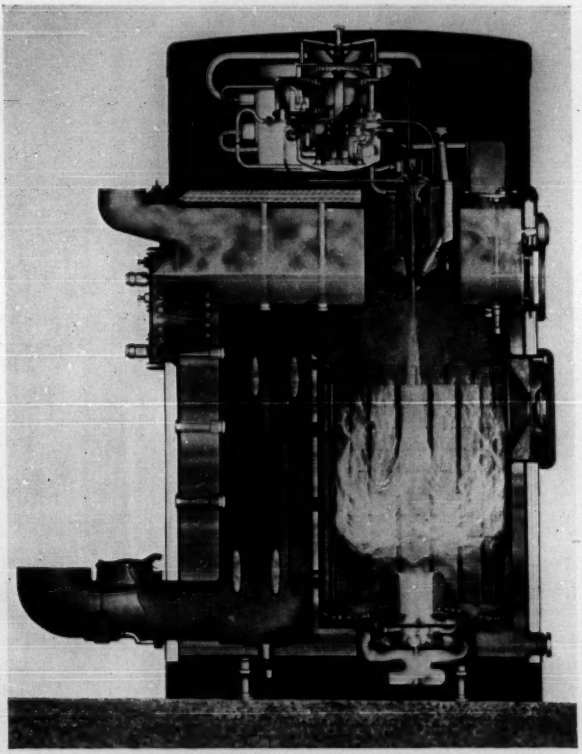
fulness of space than coal, but does not share with gas the complete freedom from storage requirements. Figure 11 shows a typical conversion oil burner and Fig. 12 a modern oil burner-boiler unit.

Coal is still the base fuel of this country, because of priority and a well developed system of supply and dis-

tribution. If and when the coal industry takes full advantage of the possibilities for automatic heat with coal as a fuel, the present downward trend of coal usage will be arrested. Figure 13 shows a typical conversion stoker with automatic coal and ash handling.

At the risk of departing from the spirit of this paper, it

FIG. 12.



Modern coördinated boiler-burner unit for burning oil.

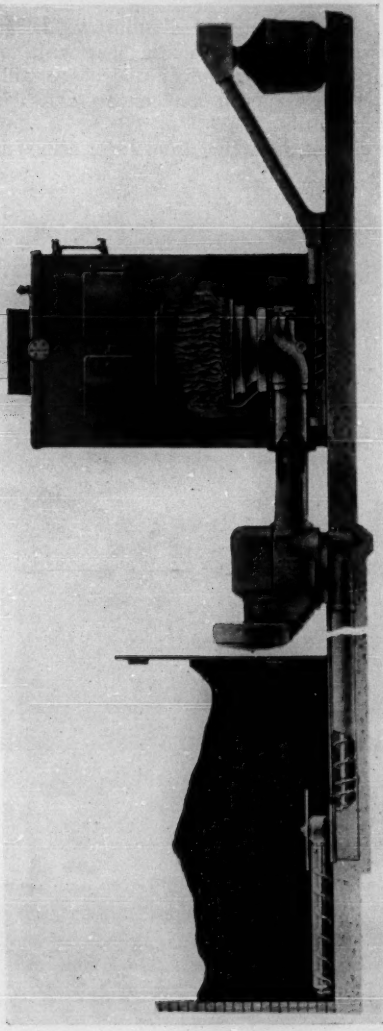


FIG. 13.

Modern coal stoker.

should be said that the open fireplace, as inefficient as it normally is, will perhaps always represent the ultimate medium for producing a friendly, hospitable atmosphere on a blustery winter night.

Table 5 gives the approximate number of centrally heated homes in the United States, and the proportion of this number using the various heating mediums:

TABLE 5.

Central Heating in the United States.

Warm air systems	8,500,000
Radiation systems	4,800,000
Total	13,300,000

	No. of Systems.	Per Cent.
Heated by gas	350,000	3
Heated by oil	750,000	6
Heated by anthracite coal	4,200,000	31
Heated by bituminous coal	8,000,000	60
Total	13,300,000	100

COOLING SYSTEMS.

In controlling air temperature, it is necessary to cool the air when it is normally above the optimum value, just as it is necessary to heat the air when it is below the optimum value.

Air cooling may be accomplished in the following ways:

1. Evaporative cooling.
2. Ice cooling.
3. Steam ejector cooling.
4. Absorption cooling.
5. Compression cooling.

Evaporative cooling refers to the transfer of heat by allowing a liquid such as water to evaporate in the enclosure which is to be cooled, the latent heat of evaporation being carried out of the enclosure by the liquid thus changed to the vapor state. The system is limited in capacity and is only practicable in atmospheres of low humidity.

Ice cooling of air has been used successfully on railway cars, in portable room coolers and other small capacity applications. Since the first cost of small cooling equipments

using ice, is less than the cost of equivalent refrigerating machines, ice cooling should be considered, where the operating season is comparatively short, and where complete portability is an important factor. However, if ice is used for cooling throughout a long season or if the cooling demand is such as to require a large ice storage, then the advantage in low first cost of the equipment is more than overbalanced by the high operating cost.

Steam ejector refrigeration may be considered one form of compression system, using a high velocity steam jet, with water as the refrigerant. Evaporation of water is intensified and the cooling capacity thereby increased, by creating a partial vacuum above the surface of the water in an air-tight tank, using a steam ejector to produce this vacuum. The water vapor and the steam are condensed in an adjoining chamber, by one of several condensing means. The system shows a favorable operating cost within the relatively narrow range of temperatures required for air cooling. It has been used successfully for railway car cooling where excess steam capacity from the locomotive is available in the summer time. It is not commercially suitable for use with air-cooled condensers or with water-cooled condensers where the cost of water is high, because the heat to be dissipated from the condenser includes the heat absorbed from the space to be cooled and also the heat of condensation from the steam used in the ejector nozzle.

Absorption systems in general, are old in the art and while somewhat complicated, are satisfactory where sufficient condenser cooling water can be obtained at low cost. Absorption systems are used in certain household refrigerators and a system using silica gel, as the absorbing medium, has been successfully applied to refrigerated freight cars.

The compression system of refrigeration is by far the most popular and widely applied, the principle being relatively simple but susceptible to many variations in the refrigerant used, the mechanical design of compressor, the prime mover and the design and application of the heat transfer surface in the evaporator and condenser. The basic principle involves the mechanical compression of some suitable gas until it becomes hot due to compression. The hot gas is then passed

through a condenser, in which comparatively large quantities of a substance lower in temperature than the compressed gas itself, absorb from it the latent heat of vaporization, so that it again becomes a liquid. This liquid, still under pressure, is then allowed to expand through an expansion valve into a compartment known as an evaporator. In this compartment, the reduced pressure allows the liquid to again vaporize, absorbing the latent heat of vaporization from the medium to be cooled, which surrounds the evaporator.

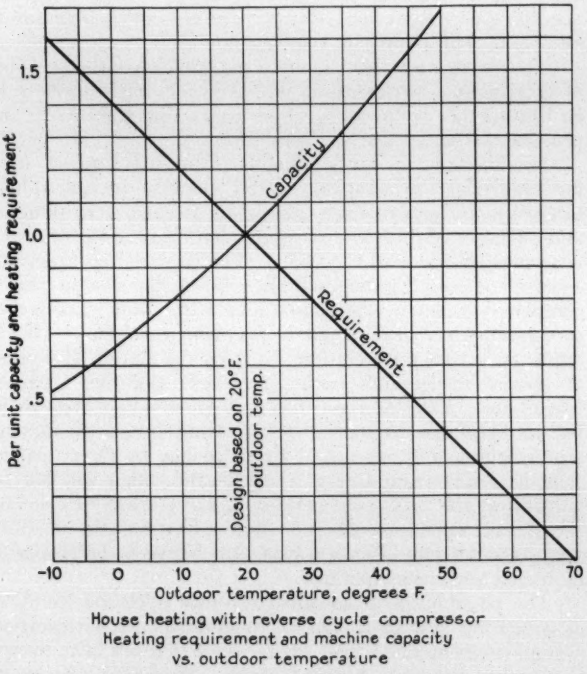
The above is a rather elemental explanation of the principle of compression refrigeration, and it is not intended here to go into further detail, other than to say that the theory and practice of this art are well established.

Regarding refrigerants, ammonia is most commonly used for industrial refrigeration, largely because it has a high latent heat of vaporization. However it has a very pungent and offensive odor and is excessively irritating to the eyes and mucous membranes of the body. Therefore it is not used for cooling homes and public buildings, unless the system can be completely isolated. Sulphur dioxide has been widely and successfully used in domestic refrigerating machines. Developments in the refrigeration art have produced a number of special refrigerants such as methyl chloride, Carrene, Freon, etc. Each of these has certain characteristics making it adaptable to special refrigerating cycles of varying temperatures and pressures. In air cooling by direct expansion, it is important to use a refrigerant which will not be harmful in the maximum possible concentration, or else use the indirect expansion method where a heat transfer medium such as water provides for a heat flow between the spaces to be cooled and the evaporator.

The possibilities of so-called reversed cycle refrigeration as a heating system should be mentioned. A refrigeration system is essentially a heat pump which delivers heat energy from a lower level to a higher level. In cooling a house in summer, heat is absorbed by the evaporator in the house and is then pumped to a higher level where it can be dissipated to the out-of-doors. Conversely, a house may be heated in winter by using a low temperature evaporator to absorb heat from the outside air and pumping this heat to a level high

enough to permit discharge inside of the house. By such a means it is possible to secure a heating effect, under proper conditions, of several times the energy input to the heat pump. In localities such as New Orleans, where the heating load in winter is about equal to the cooling load in summer,

FIG. 14.



Capacity and requirement characteristics of reversed cycle refrigerating system.

such a system will show a favorable operating cost, although with machine designs available at the present time, the first cost will be rather high.

Where extremely cold weather is encountered, the per-

formance of this system is not as favorable. If the difference between outdoor and indoor temperatures is large, the size of equipment required per unit of output increases, and the energy input per unit output also increases. Furthermore, heating in a cold climate demands a relatively high temperature of the heat source, and this high condenser temperature affects adversely both the capacity and the economy of the equipment. Figure 14 shows the variation in house heating requirements and machine capacity of the reverse cycle compressor for various outdoor temperatures, the capacity being assumed equal to the heating requirement at 20 deg. F. At lower temperatures, the heating capacity of the machine is reduced, although the heating requirement of the house is increased. Hence any heating system based on this principle must be designed to meet the most severe conditions, and will be greatly oversize for more moderate conditions.

CONTROL OF HUMIDITY.

Humidifying apparatus, used to increase the low relative humidity normally found existing in enclosures during cold weather, may be divided into three types:

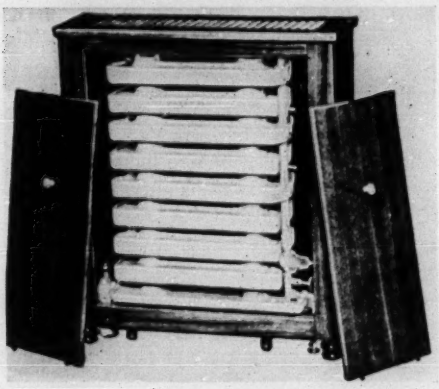
a. Mechanical.
b. Evaporative.
c. Combination mechanical and evaporative.

The mechanical type of humidifier has for its operating element either an atomizing spray of water which may be preheated to increase the evaporation, or a mechanically rotating element which throws the water off as a fine spray. In large units, the atomizing spray is suitable, because the cost per unit of evaporation can be made low. In small units, the mechanical atomizer is limited in capacity, for a reasonable cost, although the principle of operation is entirely successful, even in small portable units of one or two pounds evaporative capacity per hour.

Evaporative humidifiers have been used in one form or another for many years. Pans filled with water, on the back of radiators, and the ordinary warm air furnace evaporating pans are totally inadequate as to capacity besides giving undesirable local concentrations of high humidity. An aver-

age 15,000 cu. ft. home requires an evaporation of about three quarters of a gallon of water (about 6¼ pounds) per hour to maintain a relative humidity of 40 per cent. to 50 per cent., with severe winter conditions out-of-doors. One to two pounds of water evaporated per hour will, under the same conditions, give adequate humidity control in the average living room, provided this room is closed off to prevent the circulation of the water vapor to other parts of the house. Recently, evaporative humidifiers, with air or water preheating, or both, have been developed for application to warm

FIG. 15.



Evaporative type humidifier.

air furnaces and with sufficient capacity to produce desired results. These may be purely evaporative devices although often they combine mechanical atomization with air or water preheating, or both. The principal objection to typical evaporative humidifiers is the collection of the water solids in the evaporating pans, making frequent cleaning necessary. Figure 15 shows an evaporative type humidifier designed to replace the ordinary radiator.

In warm weather the normal moisture content of the outdoor air is too high for comfort, because when cooled, this air

approaches saturation. Therefore, during summer periods it is necessary to de-humidify when reducing temperature; in order to produce the optimum air conditions. This is accomplished either by cooling the air below the dew point to produce condensation, or by drying it out, using certain hygroscopic chemicals. When more than a very small amount of de-humidifying is desired, the condensation method is favored and it inherently is obtained where any great degree of cooling is provided for. In other words, the air to be conditioned, in coming into contact with the cold evaporative surface or the cold water spray for cooling, is reduced to a temperature below its dew-point, thereby depositing a certain portion of its water vapor on, or into, the cooling medium.

CONTROL OF AIR MOVEMENT.

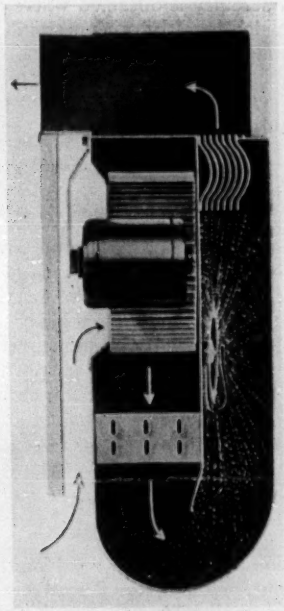
Little need be said regarding this subject except that optimum air conditions require a low velocity air movement, this movement facilitating body evaporation and at the same time tending to prevent air stagnation and heat stratification. The necessary air movement can be readily obtained by means of blowers or fans, the problem being to secure an even distribution of this movement throughout the room without noticeable drafts, and to do this with quietly-operating mechanism. In hŏmes, the proper air movement and distribution is best obtained with a central system delivering the conditioned air through a duct system, with openings into the rooms, distributing the necessary quantity of air at low register face velocities.

CONTROL OF AIR PURITY.

The elimination of suspended solid matter in air to be conditioned is relatively simple. The static filter, made up to produce many small labyrinth passes, is effective, using either dry or viscous surfaces. The first cost is low although a relatively high pressure drop is required across the filter, to effectively remove small suspensoids. The prime disadvantage of the static filter is the necessity for occasional cleaning or renewal. The air washer, consisting of sprays of finely atomized water, is commonly used in removing solid matter from the air to be conditioned. It is not subject to

cleaning if the proper amount of make-up water is used, but in small applications for homes or individual rooms, careful design is required to obtain adequate air washing without some noise and without using large quantities of water. Figure 16 shows a small air washer-humidifier suitable for installation in a room.

FIG. 16.



Mechanical atomizer type humidifier.

In the purifying of air, it is not only necessary to remove suspended solid matter but also bacteria and odors. It is here that the air conditioning art is susceptible to important further development. Filters and air washers are only partially successful in removing air-borne bacteria. Ozona-

tion, while adequate for the purifying of water, is not practicable in the purifying of air. Any concentration of ozone, sufficient to kill air-borne bacteria, produces an intolerable living condition. Air washing will only partially destroy the odors from tobacco smoke. Activated charcoal offers the possibility of producing a filter which will remove tobacco smoke and other odors not taken from the air by washing.

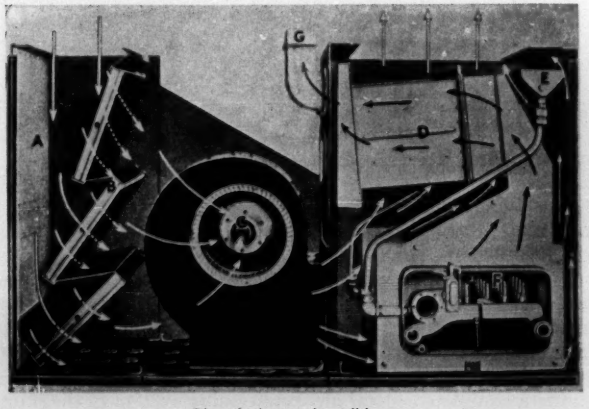
The most practicable and sure way now available for entirely removing odors is by means of sufficient new air brought in from the outside. The amount of this make-up air varies from a few per cent. in ordinary living quarters to as much as 100 per cent. under conditions prevailing in many restaurants.

AIR CONDITIONING SYSTEMS.

The principles and methods indicated above are susceptible to an almost infinite number of combinations, to produce air conditioning in various degrees of completeness.

Probably the best known combination at the moment is a winter air conditioning system consisting of a direct fired warm air furnace for heating, an evaporative type humidifier,

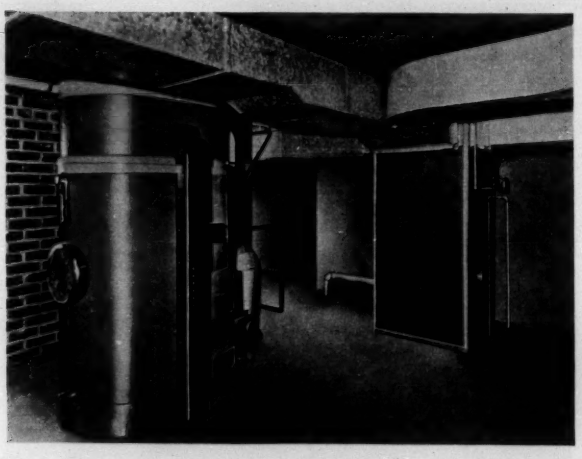
FIG. 17.



Direct fired warm air conditioner.

a blower and a static filter. A modification of this system utilizes a steam boiler connected to indirectly heat the transfer surface in the air conditioner, this surface being heated by the boiler steam. Otherwise, this system is much like the direct fired warm air system. Figure 17 shows a modern direct fired warm air conditioner and Fig. 18 shows an indirect fired warm air conditioning installation. Figure 19 shows an air conditioner which provides for air filtering,

FIG. 18.

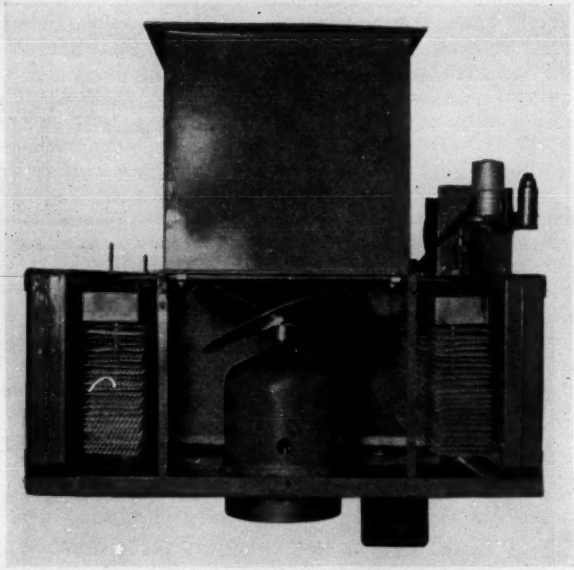


Indirect fired warm air conditioner.

humidifying and circulating. It is suitable for use with radiation heating systems to form a complete winter air conditioning system.

Central cooling systems in homes are rare at the present time since, in most cases, sufficient water at a low enough temperature for direct cooling is not available. Therefore, these systems require refrigeration of some sort, which at present involves a rather high first cost. Figure 20 shows a complete central air conditioning system in diagram-

FIG. 19.

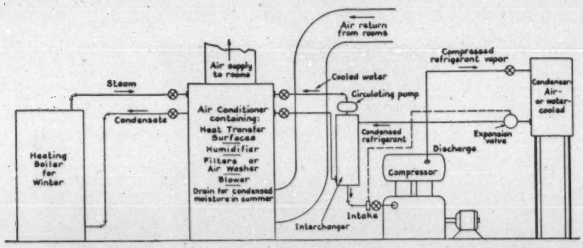


Forced circulation evaporative type humidifier and filter.

matic form, and Fig. 21 a 6 to 10 ton refrigeration unit suitable for use in homes.

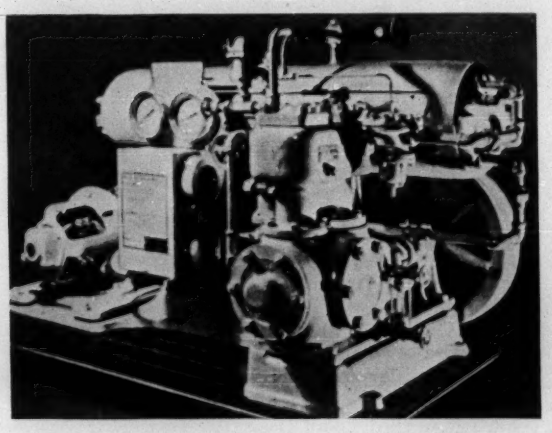
Unit air conditioners are on the market, each unit supplying complete control of the four fundamental elements of air conditioning throughout the entire year. Unit warm air conditioners are available which heat, humidify, circulate and filter in the winter time. Also unit coolers are on the market which cool, de-humidify, circulate and filter in the summer. All of these units are suitable for floor mounting, similar to ordinary steam radiation.

FIG. 20.



Schematic diagram of compression system of air cooling with complete air conditioning.

FIG. 21.



Typical refrigerating compressor—6 to 10 tons capacity.

AIR CONDITIONING IN THE FUTURE.

Some of the further developments in the field of air conditioning will be as follows:

It is recognized that the best mechanical treatment of air which is known today does not exactly reproduce the buoyant and exhilarating air conditions of a spring morning in the open

country. In other words, one or more fundamental requirements must be added to the definition of air conditioning for comfort and health, as given previously in this paper. Ionization of the air has been suggested as one essential factor. Perhaps there are other missing elements. Some day they will be fully recognized.

The effect of air conditioning on comfort is well established and it is unquestionably beneficial to health. The A.S.H.V.E. is carrying on an investigation, aiming to fully identify the benefits of air conditioning to health.

A more definite measure of comfort is needed than that given on the Comfort Chart referred to previously. In other words, a comfort meter is essential to the accurate handling of air conditioning problems. Perhaps a very exact measure of skin surface temperature will lead to the development of such a meter.

Adequate as our present heating systems are, they are susceptible to fundamental improvement. In this regard, the following quotation from a paper by Professor C. P. Yaglou of the Harvard School of Public Health is pertinent:

> It is now beginning to be recognized that our present heating methods are crude and much less healthful than Nature's method. There seems to be a great difference between the sensations of warmth, comfort, and well being, produced by solar radiation falling upon the human body on a pleasant cool day, and those which arise in rooms heated by the usual convection methods. The assertion is often made that the "common cold" and other more serious respiratory diseases begin with the heating season, and there are good reasons to suspect that the effect may be due, at least in part, to the source and nature of radiation employed in modern heating systems.

Professor Yaglou then goes on to show that the most obvious difference between heat from the sun and the heat given off by our accepted systems of heating, is the form of the heat ray. Generally speaking, our artificial heat sources emit only the "long infra-red" rays, whereas the "short infra-red," the "visible" and the still shorter "ultra-violet" rays which go to make up sunshine, are almost entirely absent. It is now believed that rays from this portion of the spectrum are essential to life and health and that many of the common winter ailments are due to the absence of the visible and ultra-violet rays of the sun.

Leonard Hill recently reported some very interesting observations to the Royal Institute of Public Health in London. Hill said that he was very sensitive to the depressing and stuffy effect produced by the "long infra-red" rays and that the direct heat from an ordinary radiator deflected the septum of his nose, closing up the left side. A dull electric fire under a well ventilated chimney produced the same effect, but when the source of radiant heat was screened from his face, the stuffiness disappeared and his nose reopened. Carrying his observations further, Hill is reported to have cut a hole in a piece of cardboard and, using this to screen his face, he breathed the warm air through the hole. In this case, the nose remained open until the screen was removed, when it closed again.

The same results were obtained from the heat radiated by coal stoves and panel heated walls, but gas or electric incandescent heaters did not produce these results. It seems fair to assume that this was because these sources of heat give off "short infra-red" rays as well as a small percentage of "visible" and "ultra-violet" rays.

Summing up the above, it seems obvious that man-made heating systems now in general use do not equal the characteristics of nature's heating system. The increasing use of sun lamps in the home is at least in the direction of overcoming this probable deficiency.

It is difficult to determine the extent of the future market for Air Conditioning apparatus because of the rapid development which is now taking place. It has been estimated that in the present state of the art, the potential market is at least five billion dollars. This does not seem excessive when one thinks of the thirty million homes in this country, over twenty million of which are electrically wired. Added to this there are twenty-five hundred large theatres, one thousand large department stores, fifteen hundred banks, not to mention the office buildings, chain stores, restaurants, hotels, specialty shops, railway trains and motor buses. It is certainly safe to say that the market possibilities are tremendous and the resultant benefits to health and comfort are well worth the investment.

On every hand, there is evidence of a growing interest in

better housing. With thirty million homes in this country, a great majority of them are either obsolete or deficient in one or more major respects. In fact, probably not one per cent. of these homes, fine as many of them are, approach the readily possible standard of comfort, convenience, cleanliness and health.

There are at least nineteen separate programs under way, all dedicated to the production of a moderate sized home erected from factory-made sections in a few days instead of three to six months, embodying equipment for comfort and health undreamed of a few years ago; all at a cost of less than half the corresponding cost with present accepted methods.

The unit kitchen, with every conceivable convenience built in, is already a reality. So is the unit laundry. It remains to amplify these and other unit principles, reduce them to practice and then obtain the distribution which will permit quantity manufacture. And what is more necessary to the health and comfort of the families who will abide in these homes, than the proper air conditions within? Air Conditioning will certainly be part and parcel of them all; inconspicuously built into the units, standardized completely and provided at a cost absurdly low when the resultant benefits are considered.

The would-be prophet is often a dangerous person to have around but, nevertheless, it does seem in order to make the following rather conservative and entirely justified prediction:

The day is coming when the air conditioning of the enclosures in which we live and work will be the generally accepted standard, and apparatus for conditioning air will be installed, even in small homes, with the same nonchalance that electric lighting and modern plumbing are now specified. The air conditioner for the home will be a single unit installed much as a boiler is now placed in the basement. It will be a perfectly standardized article, manufactured in large quantity, relatively light in weight and purchasable at a reasonable price. It will not only provide the four essential elements of air conditioning as now understood but will take care of additional factors yet to be discovered, to produce in the home a degree of comfort and health as yet unknown. The Air Conditioning Contractor will be skilled in Application Engineering, as well as in the Merchandising of his product

Air Conditioning is not a great new industry which has sprung into being over night and which, alone and unaided, will carry the country out of present economic difficulties. However, it is an industry which has been gradually growing for years, and which will continue to grow, rich in achievement and full of promise for greater health, happiness and prosperity to all mankind.

BIBLIOGRAPHY.

American Society of Heating and Ventilating Engineer's Guide.
American Oil Burner Association Handbook.
"Air Conditioning for Comfort," by S. R. Lewis.
"The Influence of Infra-Red Radiation in Relation to Heating and Ventilation," by Dr. Leonard Hill.
"How to Use the Effective Temperature Index and Comfort Charts"—A.S.H.V.E.
"Probable Future Changes in the Art of Air Conditioning," by C. P. Yaglou.
"Heat, Ventilating and Health," by D. F. Smiley, M.D., Cornell University.
"The Physiological Significance of Air Conditioning," by W. F. R. Karsten.
"Refrigeration—Past, Present and Future," by A. R. Stevenson, Jr.
"Application of Refrigeration to the Heating and Cooling of Homes," by F. H. Faust, E. W. Roessler and A. R. Stevenson, Jr.
"Ionization of the Atmosphere and its Biological Effects," by Dr. L. R. Koller.

PRINCIPLES OF STATISTICAL ANALYSIS OCCASIONALLY OVERLOOKED.

BY

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ABSTRACT.

Seven frequently overlooked sources of error in the statistical analysis of periodicities are discussed and illustrations of them are drawn from recent published discussions of cosmic-ray observations. It is shown that, through non-observance of several principles of statistical analysis, many investigators have reached incorrect conclusions as to the reliability of the periodic variations which they have deduced from their observational results. The data taken by Bennett, Stearns, and Compton on Pike's Peak, September 1931, are tested by a criterion different from that which was employed by the original investigators, from which the conclusion is drawn that the variations they observed are attributable to accidents of observation.

Some recently published discussions of periodicities in geophysical phenomena show lack of comprehensive understanding of fundamental methods by which the characteristics of such phenomena may be revealed. Variations of solar radiation, of radio reception, of cosmic radiation, etc., are essentially of a statistical nature, more complex than is usually encountered in controlled observations in the laboratory. The interest in and consequent abundance of material associated with the study of cosmic radiation make that an appropriate subject upon which to base this discussion.

Study of several papers by different investigators on the variation of cosmic radiation discloses frequent disregard of seven principles of statistical theory. We may discuss these principles individually giving illustrations from the literature of the subject. It is surprising that in many of the papers examined in which statistical methods were applied not one was free from one or more non-observances of the following principles.

(1) *The data must be sufficient to warrant statistical treatment.*—Little amplification of this precept is necessary. It is

obvious that in the investigation of diurnal variations five or ten days of observation do not constitute a "population" nor a random sample of the "parent population" in the statistical sense, regardless of how many single observations may have been made during the interval. The statistical "individual" is one complete diurnal-variation series, not one observation.

(2) *Before an error-law may be applied the form of the error-law should be investigated.*—In general it is safe to assume a Gaussian distribution, but this should always be tested to avoid fallacious conclusions.

(3) *The application of the $1/\sqrt{N}$-law requires that all of the N values be independent.*—The requirement that all N-values be independent in the $1/\sqrt{N}$-law is one of the more illusive of the seven principles which are frequently overlooked. The following illustration is taken from a paper by Corlin and Hess.[1] In discussing a series of 26 days of measurement, during which 264 day-time and 261 night-time observations were made, it is stated that the dispersion, σ, of a single observation is $\pm$ 0.407mA for the day-time values and $\pm$ 0.399mA for the night-time values, and hence the dispersions of the day-time and night-time means are $(\pm 0.407/\sqrt{264})mA$ and $(\pm 0.399/\sqrt{261})mA$, respectively. The dispersion of the day-time to night-time difference is, therefore, $\sqrt{0.025^2 + 0.025^2}mA$ or $\pm$ 0.035mA. As the difference of the day-time and night-time means is 0.13mA, nearly four times the above dispersion, it seems at first sight that a solar diurnal-variation is established, as the authors claim. But the division by $\sqrt{264}$ and $\sqrt{261}$ introduces a fallacy, for successive observations are included in the series, each of which is associated in magnitude with those preceding and following it. The fallacy of this method of treatment may be appreciated from the following consideration: If the apparatus were adapted for 5-minute registration-intervals instead of 1-hour intervals, the divisors would have been $\sqrt{12 \times 264}$ and $\sqrt{12 \times 261}$, thus reducing the dispersion to about one-third of its previously given value, and, *ad absurdum*, if the time-interval had been infinitely

[1] *Beitr. Geophysik*, 31, 169–172 (1931).

short so that an infinite number of observations could have been made, the solar diurnal-variation could have been deduced with *absolute certainty* from a single day's observations alone. Corlin [2] makes a similar error in determining the reliability of the correlation-coefficients between cosmic radiation and barometric pressure, dividing $(1 - r^2)$ by $\sqrt{N}$.

From the nature of the phenomena alone it is to be expected that successive values will be associated in magnitude. Proof of this expectation is exhibited in a paper by Steinke,[3] in which it is shown that, in a certain series of measurements, the dispersion of single values throughout a day is, on the average, $\pm 10mV$. If the values were independent, the dispersion of the daily means would be $(10/\sqrt{17})mV$ or $\pm 2.4mV$ for days on which 17 observations were made. However, it is found that the dispersion of the daily means is $\pm 5mV$, demonstrating the interdependence of successive values.

(4) *Inclusion of incomplete days in the mean vitiates the significance of a diurnal variation deduced therefrom.*—Since the daily mean values, as has been shown above, are subject to large fluctuations, inclusion of observations made during part of a day only will be reflected in the diurnal variation if the incomplete day is either high-valued or low-valued. If this restriction eliminates too many days from a given series, its severity can frequently be mitigated by interpolating one or two missing values between the adjacent ones upon which they have been shown to depend.

(5) *When the statistical fluctuations are large it is not possible to distinguish periods of similar length in a limited series of data.*—When statistical fluctuations are large it is necessary to consider the "resolving power" of a series of observations. This is particularly true of sidereal and solar periods. In a paper by Büttner [4] the effect of a solar-time variation is quite apparent in the same series of observations plotted according to sidereal time, or *vice versa*. One would naturally conclude that as 365 solar days are equivalent to

[2] *Zs. Physik*, **50**, 812 (1928).

[3] *Schr. Königsberger gelehrt. Ges.*, **7**, 128, footnote (1930).

[4] *Zs. Physik*, **45**, 595–596 (1927).

366 sidereal days, one year of observation has sufficient "resolving power" to separate the two; in fact, Steinke [5] states this as a fact. Suppose a solar diurnal-variation exists and may be represented approximately by $y = A \cos 2\pi h/24$, in which h is the unit of time. If the amplitude A undergoes a simple annual variation due, for instance, to the greater slant of the Sun's rays in winter as compared with summer, the changing diurnal-variation may be represented approximately by $y = [A' + A'' \cos 2\pi h/(365 \times 24)] \cos 2\pi h/24$, which reduces to $y = A' \cos 2\pi h/24 + (A''/2) \cos (366/365) \times (2\pi h/24) + (A''/2) \cos (364/365)(2\pi h/24)$. The second term of the right-hand side will be revealed as a spurious sidereal variation, being a period 365/366 as long as a solar day, although a sidereal variation in the physical sense, that is, caused by stellar space, may not be present at all.

(6) *If the probable error of the single values of a distribution is r, the probable error of the difference of any pair of values is* $r\sqrt{2}$.—This is obvious and is amply stated in Corlin's paper,[6] although Steinke [7] appears to have lost sight of it. Thus the probable error of the difference between *any* two points on his curve should be $\pm 2.5mV$ instead of $\pm 1.8mV$.

(7) *Several differences of the ordinates of a mean diurnal-variation curve, large in comparison with the probable error of a difference, do not establish a diurnal variation.*—Calling attention again to the last citation, Steinke concludes that as the differences between certain points on his sidereal-time curve exceed the probable error by several-fold they are to be regarded as real. His curve (sum-curve, Fig. 13, l. c., in which all ordinates appear as double their value), includes 48 observed points from which 1128 differences may be formed. That some of these differences are large is quite in keeping with statistical theory. Assuming the distribution of these differences to be normal, it is possible to compute the number which should exceed any given value. The results of this computation are shown below.

[5] *Schr. Königsberger gelehrt. Ges.*, 7, 135 (1930).
[6] *Zs. Physik*, 50, 811 (1928).
[7] *Schr. Königsberger gelehrt. Ges.*, 7, 135 (1930).

A = magnitude of difference.	A/probable error.	Occurrences of differences A.	
		Theoretical.	Observed.
$>$ 11.2	4.5	3	1
$>$ 9.7	3.9	10	4
$>$ 9.5	3.8	12	6
$>$ 8.0	3.2	35	21

Thus it is shown that the large differences in no way establish a real variation, but are even fewer than are to be expected from normal statistical fluctuations, which fact may be attributed to the special smoothing process which was employed in plotting the curve.

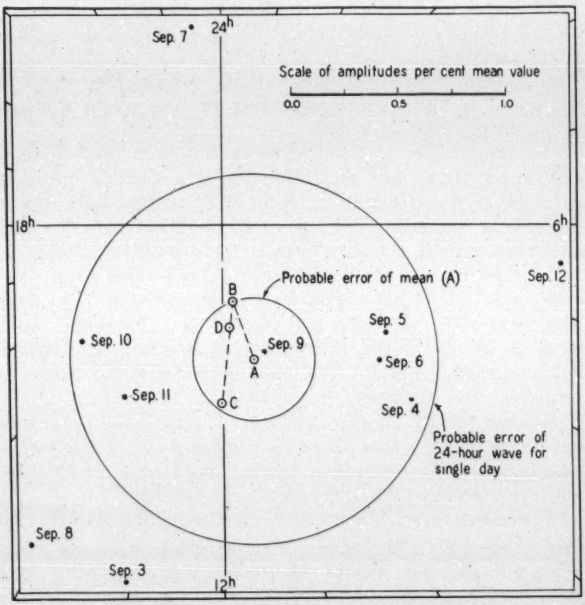
To summarize, no valid criterion has been used in these various papers to test the reliability of a diurnal variation, although such criteria exist. One of these has been applied extensively to geophysical phenomena by Bartels.[8] To illustrate this method, the data from 10 days of observation given by a graph in a paper by Bennett, Stearns, and Compton [9] were analyzed. First a Fourier analysis of each day's variation separately was made and plotted as rectangular coördinates as shown in the accompanying diagram, the cosine- and sine-coefficients for the 24-hour wave being taken as ordinates and abscissæ, respectively. The mean of the coefficients for all days is shown at A, giving the amplitude and phase of the mean diurnal-variation wave whose period is 24 hours. The root mean square deviation, σ, of all these points as measured from the mean was obtained.

The normal error-law for such a 2-dimensional distribution can be shown to be $2h\sqrt{\pi}e^{-h^2r^2}r$, in which r is any error measured from the mean. Hence one-half the points in a given normal distribution will fall within a circle about the mean whose radius is 0.833σ. This circle is shown in the diagram. Six of the ten points lie within this circle, indicating that the distribution is close to normal. As successive days do not show a regular migration about the mean, no period of similar length appears to be present, although the "resolving power" of this short series of data is too low to

[8] *Terr. Mag.*, 37, 22–27 and 291–302 (1932).
[9] *Phys. Rev.*, 41, 119–126 (1932).

separate very closely-related periods, such as the solar and the sidereal. (Indeed, this series is too short to justify statistical analysis and is being used merely for demonstration purposes because of its brevity.) The small circle about the mean is the probable-error circle of the mean, having a radius

FIG. 1.



Harmonic dial test for 24-hour wave of diurnal variation of cosmic rays, Pikes Peak, September 1931, from data reported by Bennett, Stearns, and Compton (Small circles indicate ends vectors representing wave for each day; values *A*, *B*, *C*, and *D* are means uncorrected for temperature and pressure, corrected for temperature, corrected for temperature and pressure, and corrected for temperature and pressure using correction-coefficient derived from the data, respectively).

$1/\sqrt{N}$ times as great as the probable-error circle of a single observation. Its significance is that if a large number of 10-day intervals is observed, one-half of the individual means should fall within a circle of the same radius described about

the mean of the means if the series were governed by normal statistical laws. The chance that one of these means should lie outside of a circle, the radius of which is n times the probable-error circle, is $e^{(-0.833^2 \times n^2)}$.

Corrections for temperature and barometric pressure must be applied to the data. Owing to the regular nature of the temperature- and barometric-fluctuations, the corrections for them will not seriously affect the probable error of the observations, and therefore they may be applied directly to the mean. The temperature-corrections are necessary because of the effect of temperature upon the instruments and are thoroughly sound. When they are applied, the mean is shifted to B. The barometric pressure-corrections are to compensate for the "barometer-effect" upon the intensity of the radiation. The correction-coefficient which was used by the investigators was based upon the work of Millikan and Cameron [10] under similar conditions. Its value is 0.147 per inch of mercury. When it is applied the mean is shifted to C. However, a barometric pressure-correction deduced by comparing the mean daily pressures with the mean daily values of radiation-intensity for the 10 days of this series is less than one-fourth this value, and its application shifts the mean to D.

From this analysis it is to be concluded that if the point D is accepted as the best value for the amplitude, the observed diurnal-variation may, quite likely, be an accident of observation. If the point C is accepted as the best value, the situation is improved considerably. The authors conclude, through non-observance of principle (3) above, that the chance that the observed variation is accidental is only 1 in 10,000. However, in view of the facts that this analysis is made disregarding principle (1) above and, judging from the clustering of values on September 4, 5, and 6 and values on September 10 and 11, in possible non-observance of principle (3), it cannot be adduced as a proof of the existence of a diurnal variation. A similar series of observations over another 10-day period would probably lead to quite different conclusions.

[10] *Phys. Rev.*, **37**, 242 (1931).

Violet Rays Betray Mixed Grass Seeds.—(U. S. Dept. of Agric. Clip Sheet No. 774.) Violet rays are now used to protect the American farmer, but the rays are used on grass seeds—not the farmer.

The rays, used in an almost uncanny test, make Italian ryegrass, sometimes sold as English ryegrass, reveal its true identity. When the seeds are germinated on filter paper and put in a darkened chamber and the short rays played upon them, the paper on which the roots of the Italian variety lie at once betray the seed by giving off a distinct, ghostlike glow. Even more mystifying, the apparently identical seeds of the English variety, when tested side by side with the Italian, fail to react. Some seeds of the two varieties are otherwise indistinguishable, but the English variety usually brings a higher price.

The discovery that short rays would make the filter paper fluoresce on which the roots of certain plants grow was made in Germany, and the Department has adapted it to protect American farmers in buying seed. Experimenters at first believed that special violet ray lamps were necessary to make the test, but the Department has found that using a special light filter over an ordinary light shuts out the visible rays and lets the short rays reach the paper on which the seeds have germinated, causing it to glow.

The experiments in the Department have been made by Dr. E. H. Toole, plant physiologist in the Division of Seed Investigations. The seeds are usually germinated on white filter paper, which is almost pure cellulose. Although the exact cause of the fluorescent reaction is unknown, the action of the roots on the filter paper brings about a change which causes it to glow under the short rays.

R.

CORRELATION OF FLUORESCENCE SPECTRA WITH CHEMICAL STRUCTURE OF SOME NAPHTHALENE DERIVATIVES.

BY

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INTRODUCTION.*

The phenomenon of luminescence has many practical as well as theoretical uses. Some of the more important practical uses have been in the manufacture of luminous watch and clock dials, gun sights, intensifying screens for X-ray photography, fluorescing screens for X-ray fluoroscopy and in the sensitization of photographic plates to the short ultraviolet wave-lengths.

Theoretically it has played an important part in the correlation of the physical and chemical properties of atoms and simple molecules. The theory for the more complicated molecules is now in the process of being developed. From fluorescence and absorption band spectra data, it is possible to calculate heats of dissociation, the presence and amount of isotopes and other properties of the molecule. These calculations are in good agreement with chemical observations.

Some work has been done on the luminescence of more complicated systems under various forms of excitation. Practically all of this work has been of an empirical nature from which certain, not exact, but valuable generalizations have been made (1–8).

The present paper is part of an attempt to make another important practical use of luminescence. Experiments by Newcomer (9, 10) and results which have been obtained in this laboratory, indicate that the biological effects of X-rays can be extended by converting some of the X-ray energy

* Our thanks are due to Dr. W. F. G. Swann, Director of the Bartol Research Foundation of The Franklin Institute for advice and assistance.

which is absorbed in the environment of the biological entities into fluorescent ultraviolet light. The substance used to produce the fluorescent ultraviolet light, in our case, was crystalline sodium chloride, which has a fluorescence band at about 2,500 Å. under X-ray excitation. However, a water *solution* of sodium chloride will not emit fluorescent light. Consequently, it is not suitable for producing ultraviolet fluorescent light within a body. The substance to be desired for this purpose is a non-toxic solution or a colloidal suspension which when introduced into a body will emit fluorescent ultraviolet light of the desired wave-lengths under X-ray excitation.

In examining more than seven hundred compounds for their fluorescence properties with different methods of excitation, it was found that nearly all the naphthalene sulfonic acids and salts in the solid form and in water solution showed fluorescence. A careful study of the fluorescence properties of these compounds shows a correlation between the quality of fluorescent light emitted, their absorption spectra and their chemical structure. This is in agreement with previous work (1–7). It was hoped that in making this detailed study, generalizations could be made which would be of assistance in finding a desirable substance for extending the effects of X-rays within a body.

EXPERIMENTAL PROCEDURE.

1. Fluorescence Produced by Ultraviolet Light Excitation.

The unfiltered radiation from a quartz mercury vapor arc provides an excellent source for exciting fluorescence in dilute aqueous solutions. The liquid to be examined was placed in a rectangular vessel 0.7 cm. × 2.5 cm., having a quartz window on one side and open at the top. The quartz window was placed next to the spectrograph slit and the mercury arc placed about three inches directly above the vessel. In this manner good spectrograms may be obtained in 5 to 20 minutes with a Hilger E-31 quartz spectrograph and in 10 to 90 minutes on a Hilger E-2 quartz spectrograph. If the concentration of the sample is too great, the exciting radiation will just penetrate the surface layer, the total length of the spectrograph slit will not be illuminated and a poor spectro-

gram, if any at all, will be obtained. Too dilute a solution will require an excessively long exposure. Concentrations varying from 1 part in 10,000 to 1 part in 30,000, depending on the sample, are satisfactory. Fluorescence can be detected for many of the naphthalene derivatives in concentrations of 1 part in 4,000,000.

2. Fluorescence Produced by Cathode Ray Excitation.

Practically all the energy of a cathode ray beam is absorbed in the surface layer of the irradiated samples. Consequently as compared to X-ray excitation, a very bright luminescence is usually produced. Satisfactory spectrograms can be obtained in 10 minutes.

The cathode ray tube consists of a Coolidge focusing type cathode which directs a beam of electrons into a small cylinder at the end of which is a grid which supports a .001" aluminum window. The window and cylinder are waxed onto the end of the glass tube which supports the cathode and is kept cool by a stream of water circulating through a water jacket. The tube is operated on a 130 K.V. constant potential kenetron rectified source of current. The anticathode is grounded.

The sample to be tested is placed at a 45° angle just below the aluminum window and in front of the spectrograph slit. Most of the samples cease to fluoresce after an irradiation period of about five minutes and consequently have to be renewed.

3. Fluorescence Produced by X-ray Excitation.

To determine whether any fluorescence is produced under X-ray excitation, small samples of each compound in the solid state and in various dilutions are put into a twenty-four compartment container and then placed in a beam of X-rays. A camera having a quartz lens of f-2.2 is placed above the samples and out of the exciting X-ray beam. Considerable precaution must be taken to prevent scattered X-rays from reaching the photographic plate. The camera is focused on the twenty-four samples and the whole is made light-tight so as to prevent any but the light from the fluorescing samples from reaching the photographic plate. Ninety minute exposures were taken. The presence or absence of black spots on the photographic plate gives a rough measure of the intensity of the fluorescence. By means of a mirror the samples can

also be examined visually and by comparing the intensity of the visible fluorescence with the image made on the photographic plate, an approximate estimate of the intensity of the ultraviolet fluorescence can be made. A spectrographic study was made of some of the more intensely fluorescing samples by placing each sample just in front of the slit of a small quartz spectrograph and in the X-ray beam. Exposures of from ten to twenty hours were required to get satisfactory spectrograms in this manner. This long exposure time is to be expected because only a very small fraction of the energy in the X-ray beam is absorbed in the surface layer from which the fluorescent light is emitted.

The X-rays were delivered from a constant potential kenetron rectification machine, running at 160 K.V., 4 MA., and delivering about 0.7 R per second at the samples.

4. Absorption Spectra.

Absorption spectra were taken by filling a quartz cell with the sample and placing it between the slit of the spectrograph and a hydrogen arc. The hydrogen arc emits an almost continuous radiation throughout the range of the quartz spectrograph.

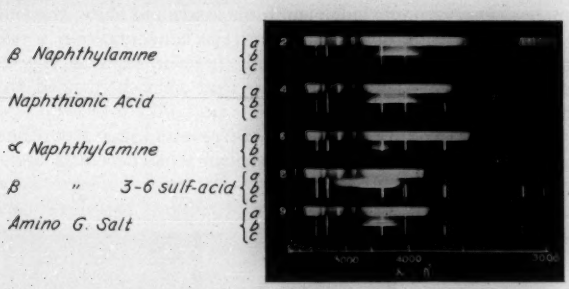
5. Analysis of Fluorescence Spectra.

The quality of the fluorescent light was readily determined by making tracings of the spectrograms on a Koch and Gooa (Krüss, Hamburg, Germany) microphotometer.

EXPERIMENTAL RESULTS.

Figure 1 shows fluorescence spectra of five naphthylamines. These are fifteen-minute exposures under the mercury arc excitation, taken on the Hilger E-2 spectrograph and are typical of all the spectra from which data were taken when the exciting source was the mercury arc. The top exposure (*a*) of each group of three is the absorption spectrum, the middle one (*b*) is the fluorescence spectrum, and the bottom one (*c*) is the mercury arc spectrum which was used as the exciting source. Scattered and reflected light from the exciting source is plainly seen in (*b*) but is easily distinguishable from fluorescent light. Variations in the absorption as well as in the fluorescence spectra are easily noticeable.

FIG. I.



(*a*) Absorption and (*b*) fluorescence spectra of certain naphthylamine compounds together with (*c*) the mercury arc spectrum which was used as the exciting source of radiation.

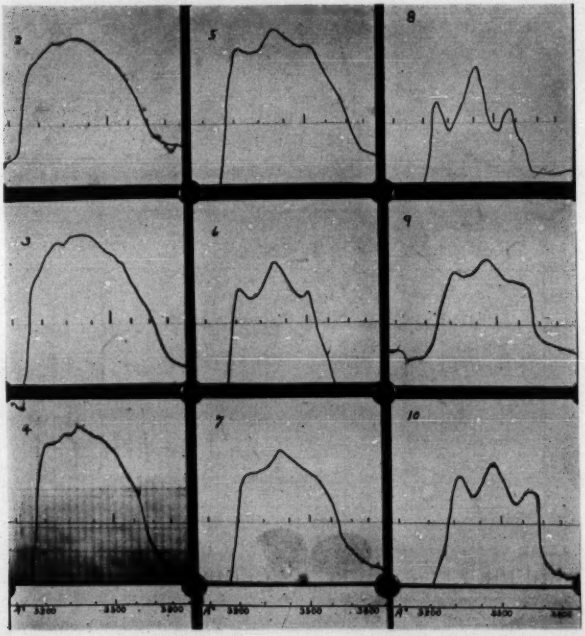
TABLE I.

No.	Name	Structure	%Conc.	Dens. Tracing	Intensity	Approx. spectral limits A	Max. A	Sub Max. A	CATHODE Approx. Spectral Limits A	X-RAY EXCITATION Intensity: Solution	Solid	Approx Spect Limit
1	Naphthalene		.04			3130 - 3800			3300 - 3300	0	6	
2	" α sulf. acid		.01		20	3130 - 4220	3350		3350 - 4900	0	4	
3	" α Na sulfonate		"		20	3140 - 4000	3350		3350 - 5200	0	5	
4	" 1-5 Na sulfonate		"		20	3170 - 3650	3350	3230	3300 - 4700	1	7	
5	" β sulf. acid		"		20	3170 - 3800	3290	3250 3350	3350 - 4900	0	6	3600 - 4800
6	" β Na sulfonate		"		7	3170 - 3650	3290	3250 3350	3300 - 4900	1	8	3200 - 4000
7	" 1-6 Na sulfonate		"		12	3200 - 3700	3410	3260 3350	3300 - 5400	0	3	
8	" 2-7 Na sulfonate		"		5	3210 - 3750	3410	3260 3350	3300 - 5400	0	4	
9	" 2-6 sulf. acid		"		11	3200 - 4000	3450	3310 3430	3500 - 5200	0	2	
10	" 2-6 Na sulfonate		"		8	3230 - 3800	3450	3310 3430	3500 - 5400	0	2	
11	Mixture of " 1-3-6 Na " " 1-3-7 "		"		21	3250 - 4000	3440		3300 - 5300	0	0	

Figure 2 is a group of densitometer tracings of the fluorescence spectra of naphthalene sulfonic acids and salts, the time of exposures being 90 minutes and the concentration 1 part in 10,000 of water. To enable reducing and reproducing the original tracings it was necessary that they be traced free hand with pen and ink.

Table 1 gives a compilation of the results taken from these tracings. Column 6 represents the area of the curve above

FIG. 2.

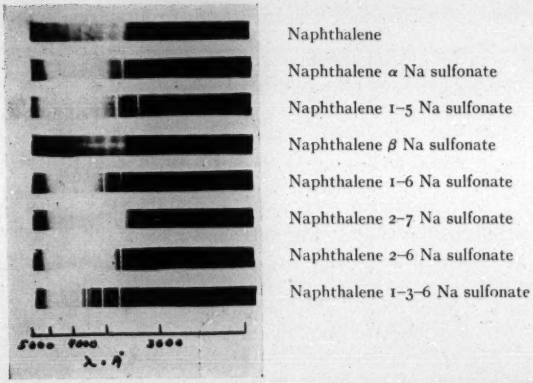


2. Naphthalene α sulfonic acid.
3. Naphthalene α sodium sulfonate.
4. Naphthalene 1–5 sodium sulfonate.
5. Naphthalene β sultonic acid.
6. Naphthalene β sodium sulfonate.
7. Naphthalene 1–6 sodium sulfonate.
8. Naphthalene 2–7 sodium sulfonate.
9. Naphthalene 2–6 sulfonic acid.
10. Naphthalene 2–6 sodium sultonate.

Densitometer tracings of the fluorescence spectra of certain naphthalene compounds.

the base line and is a rough measure of the intensity of fluorescence. Column 10 shows the approximate spectral limits in Angstrom units of the fluorescence spectra when excited by cathode rays. (Figure 3 shows a group of these fluorescence spectra which are approximately fifteen-minute exposures and taken on a Hilger E-31 quartz spectrograph.) Columns 11 and 12 represent roughly the intensity of fluorescence as estimated from the blackness produced on the photographic plates of the previously described camera. The blackness produced by a sample of calcium tungstate

FIG. 3.



Fluorescence spectra of certain naphthalene compounds under cathode ray excitation.

was taken as ten. Column 13 gives the approximate spectral limits of X-ray excited spectra.

Following is a description in detail of the correlation:

1. Naphthalene is so insoluble in water that it was impossible to obtain the data with an aqueous solution.

Stark and others have shown, however, that the fluorescence spectrum of an alcoholic solution of naphthalene consists of 9 or 10 bands extending from about 3130 to 3800 Å. This is of shorter wave-length than any of its derivatives tried. Although the solvent affects the fluores-

cence to some extent, nevertheless this would tend to show, in agreement with previous work, that the substitution of larger groups for an H atom in the ring shifts the spectrum toward the red (2, 4, 5, 6).

2. Derivatives containing a single HSO_3 group.

(*a*) In the α position the curve has no well defined maximum (Nos. 2 and 3).

(*b*) In the β position the curve shows three well defined maxima. The principal maximum has a slightly longer wave-length than that of the α compound (Nos. 5 and 6).

3. Derivatives containing two HSO_3 groups.

(*a*) 1–5 naphthalene Na sulfonate (No. 4) gives a curve similar to that of the α sulfonate. This compound may be regarded as having two α substitution groups, one in each ring.

(*b*) 2–7 naphthalene Na sulfonate (No. 8) and 2–6 naphthalene sulfonic acid and Na sulfonate (Nos. 9 and 10) give curves similar to that of the β sulfonate in shape, but with a shift toward the red of the maxima. These compounds may be regarded as having two β substitutions and therefore a doubling of the β substitution effects.

(*c*) 1–6 naphthalene Na sulfonate (No. 7) shows the characteristics of the α sulfonate and the β sulfonate. It may be regarded as having an α substitution and a β substitution. The wave-length of the maximum is greater than that of 1–5 naphthalene Na sulfonate but less than that of the 2–6 or 2–7 naphthalene Na sulfonate.

4. Derivatives containing three HSO_3 groups.

The mixture of 1–3–6 and 1–3–7 naphthalene Na sulfonate (No. 11) shows a flattening out of the curve and a shift of the maximum toward the red.

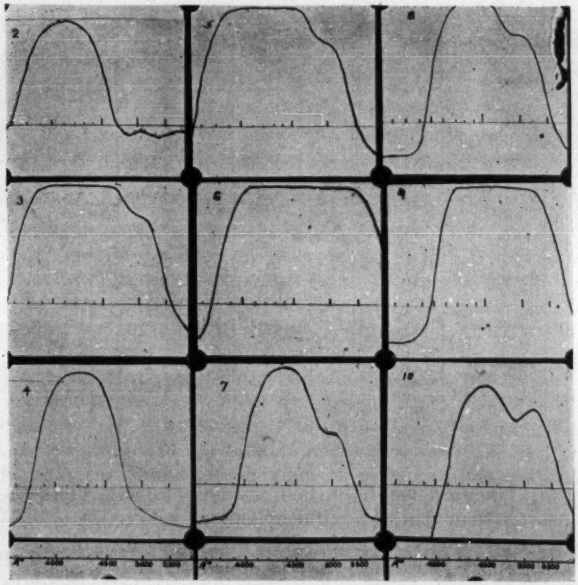
5. The fluorescence produced by cathode ray excitation is roughly in the same region as that produced by ultraviolet light excitation.

6. The intensity of fluorescence produced by X-ray excitation does not correlate with that produced by ultraviolet light excitation.

Figure 4 shows a group of tracings similar to those of Fig. 2 except that they are of the fluorescence spectra of the naphthylamine sulfonic acids and salts. Table 2 is also

a compilation similar to Table I of the data taken from these tracings. It was necessary to re-take some of the fluorescence spectra with shorter exposure periods to determine more accurately the maxima and submaxima. Some of the data were taken from tracings made of the spectra shown in Fig. 1.

FIG. 4.



2. β Naphthylamine.
3. β Naphthylamine 6 sulfonic acid.
4. Naphthionic acid.
5. Sodium naphthionate.
6. α Naphthylamine.
7. β Naphthylamine 8 sulfonic acid.
8. β Naphthylamine 3–6 sulfonic acid.
9. Amino G.
10. α Naphthylamine 3–7 sulfonic acid.

Densitometer tracings of the fluorescence spectra of some naphthylamine compounds.

Following is a detailed description of the correlation:

1. Derivatives containing a single NH_2 group.

(*a*) Neither α naphthylamine (No. 6) nor β naphthylamine (No. 2) gives a curve with well defined maxima.

TABLE 2.

		ULTRAVIOLET EXCITATION								CATHODE	X-RAY EXCITATION		
No.	Name	Structure	Conc.	Dens. Tracing	Intensity	Approx. Spectral Limits A	Max. A	Sub Max. A		Approx. Spectral Limits A	Intensity Solution	Intensity Solid	Approx Spectra Limits
1	β Naphthylamine 1 sulf. acid		.01%			3700 – 4800	4050				0	0	
2	β Naphthylamine		.005%		27	3700 – 4700	4100			3800 – 5500	0	4	
3	β " 6 sulf acid		"		27	3700 – 5500	4250			4000 – 5000	0	0	
4	Naphthionic acid		"		55	3650 – 5700	4270	5100		——	0	0	
5	Na Naphthionate		"		51	3650 – 5700	4270	5100		3700 – 4800	0	6	3500 – 5000
6	α Naphthylamine		"		59	3650 – 6400	4300			3900 – 5000	0	0	
7	β " 8 sulf. acid		"		29	3900 – 5800	4350	5100		3500 – 5200	0	1	
8	β " 3-6 " "		"		38	3900 – 5800	4400	5100		4000 – 5000	0	1	
9	Amino G acid		"		47	3950 – 5950	4450	5100		——	0	0	
10	α Naphthylamine 3-7 Na sulf.		.01%		29	3950 – 6000	4450	5100		4000 – 4900	0	0	
11	α Naphthylamine 3-7 Na sulf.		.005%		18	4150 – 6200	4550	5100			0	0	

Fluorescence of naphthylamine sulfonic acids and salts.

(*b*) The wave-length of the maximum of β naphthylamine is shorter than that of α naphthylamine.

2. Derivatives containing NH_2 and one HSO_3 group.

(*a*) For the few compounds examined (Nos. 1, 3, 4, 5, 6, 7) all the β naphthylamines except β naphthylamine 8 sulfonic acid (No. 7) give curves having maxima of shorter wave-length than the α naphthylamines.

(*b*) β naphthylamine 1 sulfonic acid (No. 1) fluoresced only faintly and no satisfactory densitometer tracing was made, but its maximum was judged to be at 4050 Å. which is shorter than that of β naphthylamine. The wave-length of the maxima of naphthionic acid and its sodium salt (Nos. 4 and 5) is shorter than that of α naphthylamine (No. 6).

This would indicate that where the HSO_3 and NH_2 groups are on the same ring the influence of the HSO_3 group is strong enough to reduce the wave-length of maximum fluorescence below that of compounds containing only the NH_2 group.

3. Derivatives containing NH_2 and two HSO_3 groups.

(*a*) In this group of compounds (Nos. 8, 9, 10, 11) the β naphthylamines give curves with maxima of shorter wave-length than the α naphthylamines.

(*b*) Addition of more radicals increases the wave-length of the maximum.

4. General conclusions:

(*a*) The NH_2 radical shifts the fluorescence band considerably toward the red end of the spectrum, the α position more so than the β position.

(*b*) The NH_2 compounds give much more intense fluorescence under ultraviolet light excitation than the HSO_3 compounds alone.

(*c*) The fluorescence produced by cathode ray excitation is roughly in the same region as that produced by ultraviolet light excitation and, in the one case tried, is practically the same as that produced by X-ray excitation.

(*d*) The intensity of fluorescence is not the same for X-ray and ultraviolet light excitation.

Figure 5 shows a group of tracings similar to Figs. 2 and 4. Tracings 1, 2, 3, 4, 5, and 6 are of the naphthols and the data are compiled in Table 3. Tracings 1*a*, 2*a*, 3*a*, 4*a*, and 5*a* are of compounds having both OH and NH_2 radicals and a compilation of the results taken from these tracings is given in Table 4.

Following is a detailed discussion of Table 3.

1. Derivatives containing a single OH group.

(*a*) β naphthol (No. 1) gives densitometer tracings with a number of maxima and minima.

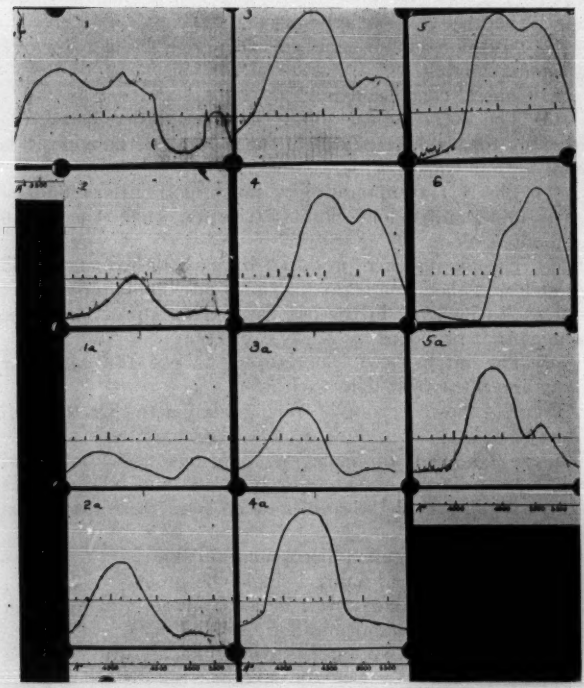
(*b*) α naphthol (No. 6) is so insoluble in water that a densitometer curve was unobtainable, but from a faint spectrogram, the wave-length of the maximum appeared to be much longer than that of β naphthol.

2. Derivatives containing one OH and one HSO_3 group.

(*a*) For the compounds examined (Nos. 2, 3, 4, 5) the wave-length of the maximum of β naphthol 6 sulfonic acid

(No. 2) is shorter than any α naphthol, and β naphthol 8 sulfonic acid (No. 4) and β naphthol 7 sulfonic acid (No. 5) as estimated from a faint spectrogram give a maximum of shorter wave-length than α naphthol. This is similar to the

FIG. 5.



1. β naphthol.
2. β naphthol 6 sodium sulfonate.
3. α naphthol 4 sodium sulfonate.
4. β naphthol 8 sodium sulfonate.
5. G salt.
6. β naphthol 3–6–8 sodium sulfonate.

(1a) 1 amino 8 hydroxy 6 sulfonic acid.
(2a) S acid.
(3a) H acid.
(4a) J acid.
(5a) B acid.

Densitometer tracings of the fluorescence spectra of some naphthol and other naphthalene compounds.

TABLE 3.

No.	Name	Structure	Conc.	Dens. Tracing	Intensity	Approx. Spectral Limits A	Max. A	Sub Max. A	Approx. Spectral Limits A	Intensity Solution	Intensity Solid	Approx. Spectral Limits A
	ULTRAVIOLET EXCITATION								CATHODE	X-RAY EXCITATION		
1	β Naphthol		.005%		20	3350 – 4800	3800		3500 – 5300	0	2	
2	β " 6 Na sulfonate		"			3650 – 4550	4250	4400	4300 – 5000	0	0	
3	α " 4 " "		"		54	3480 – 6200	4550	5100	4400 – 5000	0	0	
4	β " 8 " "		.01%		25	3700 – 6300	4400	5100	3900 – 5000	0	0	
5	β " 7 " "		.005%			4050 – 5800	4400			0	0	
6	α Naphthol		"			3650 – 5500	4520		3500 – 5000	0	0	
7	G salt		"		51	4050 – 6300	4550	5100	3600 – 4800	2	6	3700 – 6000
8	β Naphthol 3-6-8 Na sulf.		.002%		16	4550 – 6300	5150	4550	4200 – 5000	0	0	

Fluorescence of naphthol sulfonic acids and salts.

naphthylamines except that the α naphthol maximum is of longer wave-length than all of the β naphthols.

(*b*) The only compound tried (No. 3) in which the OH and $NaSO_3$ groups are on the same ring shows, as with the naphthylamines, a shift of the maximum toward the blue as compared to a single naphthol without a $NaSO_3$ group.

3. Derivatives containing one OH and two or three HSO_3 groups.

(*a*) The two salts tried (Nos. 7 and 8) show an increase in the wave-length of the maximum with the addition of more radicals.

4. Under cathode ray excitation the fluorescence bands are again approximately in the same wave-length regions as those produced by ultraviolet light excitation. This is also true for the one case tried with X-ray excitation.

From Table 4, it is impossible to obtain any generalization except that the fluorescence is in the same general

TABLE 4.

			ULTRAVIOLET EXCITATION						CATHODE	X-RAY EXCITATION	
No.	Name	Structure	Conc.	Dens. Tracing	Intensity	Approx. Spectral Limits A	Max. A	Sub Max. A	Approx. Spectral Limits A	Intensity Solution	Intensity Solid
1	1 amino 8 hydroxy 6 sulfonic acid		.005%			5650 - 5500	5950	5550		0	0
2	S Acid		"		6	5700 - 5500	4100		----	0	0
3	R Acid		"		5	5650 - 5500	4150		----	0	0
4	J Acid		.0025%		21	5650 - 5500	4250		----	0	0
5	B Acid		.005%		12	5650 - 5500	4400	5100		0	0

Fluorescence of certain naphthalene derivatives.

region as that of the naphthylamines and naphthols. The fluorescence produced under X-ray and cathode ray excitation was nil.

The way in which the wave-length maxima vary under ultraviolet light excitation with the molecular structure is summarized in the graph of Fig. 6.

The following generalizations may be made from all the data:

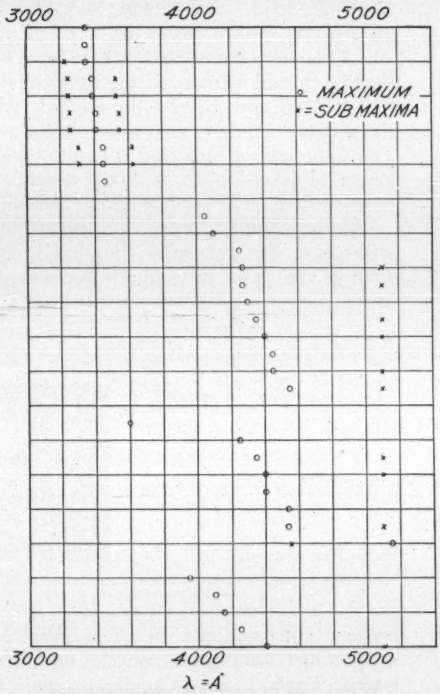
1. The wave-length of the maxima for the salts and the acids is the same; the maxima are sharper for the salts. In general the intensity of fluorescence produced by ultraviolet excitation is greater for the acids than for the salts but for X-ray excitation the reverse is true.

2. The wave-length maxima are independent of the concentration but the intensity of fluorescence is affected.

3. Two different samples of the same compound give identical densitometer tracings tending to show that fluorescence is an exact function of the chemical structure. Samples which were several years old and obtained from Germany gave identical fluorescence spectra with samples obtained from the du Pont Jackson Laboratories.

FIG. 6.

No.	Name.
1	Naphthalene
2	Naphthalene α sulf. acid
3	Naphthalene α Na sulfonate
4	Naphthalene 1–5 Na sulfonate
5	Naphthalene β sulf. acid
6	Naphthalene β Na sulfonate
7	Naphthalene 1–6 Na sulfonate
8	Naphthalene 2–7 Na sulfonate
9	Naphthalene 2–6 sulf. acid
10	Naphthalene 2–6 Na sulfonate
11	Naphthalene 1–3–7 Na sulfonate
1	β naphthylamine 1 sulf. acid
2	β naphthylamine
3	β naphthylamine 6 sulf. acid
4	Naphthionic acid
5	Na naphthionate
6	α naphthylamine
7	β naphthylamine 8 sulf. acid
8	β naphthylamine 3–6 sulf. acid
9	Amino G acid
10	α naphthylamine 3–7 Na sulf.
11	α naphthylamine 5–7 Na sulf.
1	β naphthol
2	β naphthol 6 Na sulfonate
3	α naphthol 4 Na sulfonate
4	β naphthol 8 Na sulfonate
5	β naphthol 7 Na sulfonate
6	α naphthol
7	G salt
8	β naphthol 3–6–8 Na sulf.
1	$1NH_28OH6HSO_3$
2	S acid
3	H acid
4	J acid
5	B acid



A graph showing the relation of fluorescence excited by ultraviolet light to the chemical structure of a number of naphthalene derivatives.

According to Stark (2) an alcoholic solution of

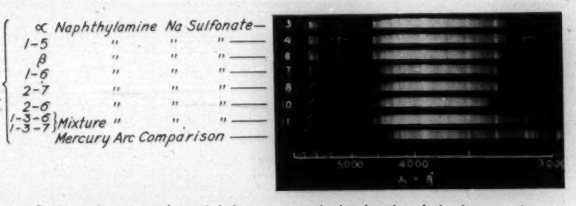
α naphthol fluoresces in the region of about 3200–5100 Å.,
β naphthol fluoresces from about 3300–4750 Å.,
α naphthylamine fluoresces from about 3600–5100 Å.,
β naphthlyamine fluoresces from about 3650–4900 Å.,

which is in good agreement with results given above.

Absorption spectra of some of the naphthalene sulfonates were obtained. Seven solutions were prepared and their absorption spectra taken on a single plate in the order in which they are mentioned in Fig. 6. The plate is reproduced in Fig. 7 and shows an unmistakable correlation between fluorescence and absorption spectra, with the exception of the mixed trisulfonic acid which was not a very pure sample. The fluorescence radiation is a few hundred Angstrom units longer in wave-length than the absorbed radiation which is in agreement with previous observations (1, 5, 6, 7).

Many samples show a very decided change in their absorption spectra after having been irradiated. These changes are probably photochemical changes due to the irradiation which affects the quality of the emitted fluores-

FIG. 7.



Spectrograms of certain naphthalene compounds showing the relation between the absorption spectra and chemical structure.

cence. The rapidity with which these photochemical changes are produced depends upon the nature of the exciting radiation. Cathode rays usually produce very rapid changes. This phenomenon helps to explain the slight differences in the quality of fluorescence emitted under different methods of excitation.

Six fluorescence spectra were taken on a Hilger E-1 quartz spectrograph, which has a high dispersion and resolving power but the bands still appeared to be continuous, i.e., no line structure was detectable.

Table 5 gives a list of ten compounds which were examined and showed only a very faint fluorescence under ultraviolet light excitation and no fluorescence under X-ray excitation.

TABLE 5.

A Number of Naphthalene Derivatives which Give Only Faint Fluorescence under Ultraviolet Light in Aqueous Solution.

1. Laurent's acid 1 amino 5 sulfonic acid.
2. Cleve's acid 1 amino 7 sulfonic acid.
3. Peri acid 1 amino 8 sulfonic acid.
4. Dahl's acid 2 amino 5 sulfonic acid.
5. 1–8 amino 3–6 sulfonic acid.
6. 1 hydroxy 3–6 sulfonic acid.
7. 2 hydroxy 3 sulfonic acid.
8. 2 hydroxy 3–6 sulfonic acid.
9. 1–8 hydroxy 3–6 sulfonic acid.
10. 1 amino 2 hydroxy 4 sulfonic acid.

None of these compounds in the solid state fluoresces to X-rays except No. 8 which fluoresces only faintly.

SUMMARY.

A definite relation is shown to exist between the chemical constitution of certain naphthalene derivatives and their fluorescence and absorption behavior. The naphthalene, naphthylamine and naphthol compounds vary in intensity and region in which they fluoresce. When a radical is changed from an α to a β position, a shift in wave-length of the maximum intensity occurs. From the shape of the densitometer tracings a difference between an acid and its salt is readily discernible.

The quality of fluorescence is roughly the same whether the source of excitation be ultraviolet light, X-rays or cathode rays. It is also independent of the concentration and, in the case of the specimens studied, independent of small amounts of impurities.

BIBLIOGRAPHY.

1. Stark, J. und Meyer, R. Beobachtung ueber die Fluorescenz von Benzol Derivaten. *Phys. Zeit.*, **8**, 250 (1908).
2. —— und Steubing, W. Fluorescenz und Lichtelectrische Empfindlichkeit organischer Substanzen. *Phys. Zeit.*, **9**, 480 (1908).
3. ——. Ueber den Zusammenhang zwischen Fluorescenz und Chemischer Konstitution. *Z. f. Electrochem.*, **18**, 1011 (1918).
4. Ley, H. und Englehardt, K. V. Ueber die Ultra Violette Fluorescenz und Chemische Konstitution bei zyklischen Verbindungen. *Z. f. phys. Chem.*, **74**, 1 (1910).
5. Handbuch der Physik—Geiger und Scheel, Vol. 23, Chap. 5. Berlin, 1926.
6. Handbuch der Experimental Physik—Wien und Harms, Vol. 23, Part 2, Chap. 13. Leipsig, 1928.

7. Pringsheim, P. Fluorescenz und Phosphorescenz. Berlin, 1928.
8. Perrine, J. O. A Spectrographic Study of Ultraviolet Fluorescence Excited by X-Rays. *Phys. Rev.*, Series II, **19**, 538 (1922).
9. Newcomer, H. S. Bactericidal Fluorescence Excited by X-Rays. *Journ. Exp. Med.*, **26**, 657 (1917).
10. ——. The X-Ray Fluorescence of Certain Organic Compounds. *Journ. Am. Chem. Soc.*, Vol. 42, No. 10, 1997. 1920.

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A SYSTEM OF TEMPERATURE CONTROL.

BY

HUGH H. DARBY, Ph.D.,
Bartol Research Foundation of The Franklin Institute, and

CALVIN B. BRIDGES, Ph.D.,
California Institute of Technology.

BARTOL RESEARCH FOUNDATION.
Communication No. 74.

In the Mexico City Station, Bureau of Entomology, U. S. D. A., and later at the Bartol Research Foundation, Swarthmore, Pa., several incubators have been working with a normal variation of not more than .05° C. for an appreciable length of time. These incubators were installed by one of us, H. H. Darby. Since this degree of accuracy is considerably greater than that usually obtainable in a biological laboratory and yet is highly desirable, we have thought it worthwhile to describe the methods and materials used.

The system as a whole comprised an insulated chamber, a heating unit, a fan, a thermostatic control and a magnetic switch (converted telegraphic sounder). The chamber itself was designed by Dr. C. I. Bliss, and others, using the general type of construction and the closed system of air circulation as customarily employed by Bridges, and was later modified by Darby with respect to the air supply. It consisted of a wooden box about 44 in. long by 18 in. wide by 21½ in. deep. The box was made of one layer of five-ply on the outside, followed by a layer of cork sheeting (1 in. thickness), followed by a layer of celotex, and lined inside with transite (asbestos cement or celotex). (For incubators intended to hold 15° C. or more above room temperature, an additional layer of celotex between the five-ply and the cork would be advantageous.) Most of the front face of the box was occupied by a pair of doors with double panes of glass. Between the inside and outside pane was an air space about an inch across, to provide insulation. The doors were bevelled, and all surfaces where door and box made contact were padded with

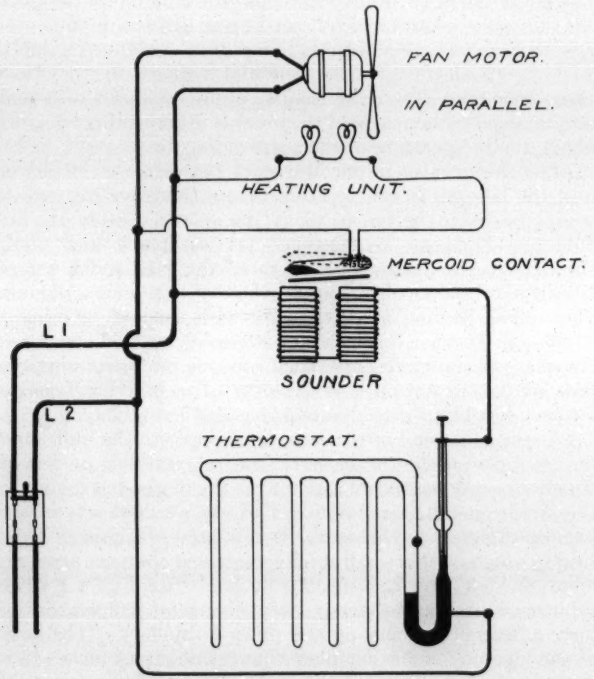
felt to prevent air exchange through the cracks. Inside the incubator was a shelf which filled the entire width, but did not reach the ends of the box, since enough space was left to accommodate the heating unit at one end and the thermostatic control at the other. Each end of the shelf was supported by a partition, in practice a sheet of five-ply. These supports projected a few inches above the shelf. In one of them, at a position suitable to accommodate a fan, a hole was cut, with diameter slightly greater than that of the fan blades. The diameter of fan blades was seven and a half inches. At the bottom of the other support a gap of about two inches was left for air currents to pass back to the fan. This construction provided a closed circuit which the air was forced to follow.

In the plans as originally drawn, no provision was made for any exchange of air with the outside, except by the occasional opening of the doors. It was found that a small alcohol lamp could not burn for more than a minute in the box with the doors closed. This situation could be highly detrimental, especially for organisms sensitive to oxygen lack. Organisms of course consume oxygen at a much slower rate than an alcohol burner, so that the difficulty was readily overcome by boring two air vents about an inch in diameter at different levels in one end of the box. Thermal equilibrium was not disturbed by this change, and an adequate supply of oxygen was assured. A better location of the holes would have been through the back of the incubator—one on the negative pressure, one on the positive pressure side of the fan partition.

The heating unit consisted of a pair of electric bulbs, set in series with each other on the floor of the incubator outside of the first-mentioned shelf support. The series arrangement of the lamps burned them at half the rated voltage, and consequently the incubator seldom failed from their burning out. The size of the bulbs was varied, from 25 to 125 watts, depending on the difference between the room and the incubator temperatures. If the minimum wattage which could handle the temperature gradient between incubator and laboratory was used, if ever the controls failed to function and left the heaters on, the incubator temperature could not

go very high above that at which it was being kept. This practice has often kept material from being killed by overheating. The heating circuit was wired as follows: from the line through the lamps to the mercoid contact, and back to the line. (See Fig. 1.)

Fig. 1.



The fan was so placed that the blades revolved in a hole in the supporting partition mentioned above, and drove an air current over the bulbs, across the roof and down to the floor again at the other end. (The reverse direction is even better, since the natural stratification of air is counteracted

by sending the warmed air across the bottom of the box.) It was surprising how large a fan was necessary to maintain thermal equilibrium in so small a box. The six-inch fans used at first were soon replaced by others with larger blades ($7\frac{1}{2}$ in. diameter) and higher speed, since with the small ones there was a gradient of about a degree between the top and bottom of the box. For continuous service, a motor designed for that purpose and which heated up as little as possible was essential, as was also adequate lubrication. Motors equipped with cups for heavy grease were found more satisfactory than those with oil wicks. The best we obtained, by its own heat and unaided by lamps, held the incubator about three degrees above the temperature of the surrounding air.

For this reason, if the difference between the incubator and the laboratory temperature is less than five degrees, it would be much better to place the motor outside the incubator. Such an arrangement necessitates a long shaft through the incubator wall to carry the fan, and a set of bearings to support this shaft. Darby has used a lignum vitæ oilless bearing for such work with success. Failing a hardwood bearing, a loose end-coupling would be best. Another possibility recently tried was one motor running the fans by a belt system over pulleys. The individual motor for each incubator placed outside has distinct advantages.

At the other end of the incubator, opposite the bulbs and fan, was placed the thermostatic control, standing on felt or cotton to cut down the vibration from the motor and minimize the strain on the glass joints. The one we used was of the pattern designed by Bridges. It consisted of a grid of glass tubing which, with a small total volume and compact arrangement, held a long column of toluene. (See Fig. 1.) The toluene expands and contracts with change of temperature to force a head of mercury up and down a capillary. The level of the mercury in the capillary changes about $1\frac{1}{2}$ inches to a degree, so that a screw plunger can control the point of equilibrium within .01° C. This apparatus can be obtained from Mr. Graham at the University of Pennsylvania, who has copies of the plans, and has been making them for sometime.

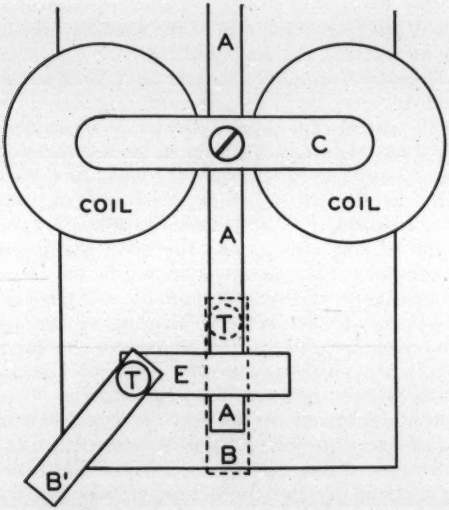
The feature in which we were most interested was a

mechanism whereby the thermostatic control could turn the heating unit on and off. The apparatus developed for this purpose was an ordinary telegraphic sounder, with the addition of a mercoid vacuum tube and with some other modifications which will be described. The sounder was connected in series with the thermostat. (See Fig. 1.) As the temperature in the incubator goes up, the level of the mercury rises in the capillary of the thermostat, until it makes contact with the plunger. This closes a circuit that flows from the line through the thermostat and the coils of the sounder to the other side of the line. The arm of the sounder, which carries on it a long mercoid vacuum tube (about 7 cm. long, made by the Mercoid Contact Company of Chicago), is pulled down, and the mercury in the mercoid contact runs forward, breaking the circuit that supplies the lamps for heat. As the incubator cools, the contact is broken in the thermostat, the current ceases to flow in the sounder coils, and the arm of the sounder is released, to return to its original position by the action of a spring. The mercury in the contact runs back to close the heating circuit, and the cycle is complete. In order to cut down the amount of arcing in the thermostat, and the consequent oxidation of mercury, the fan motor was connected up in parallel with the thermostat and also with the heating circuit. This arrangement gave the line a much greater capacity, and consequently when the thermostatic contact was broken there was very little arcing. One thermostat, after continuous use for two years and four months, without a change of mercury, still held its incubator to within .05° C. Another wiring system was tried in which the arcing from the mercury to the contact point was cut down by placing a 2 M.F. condenser across the gap. This, in practice, does not work as well as the wiring diagrams here given but is possible.

The modifications introduced in the telegraphic sounder were concerned with maintaining a delicate balance between the spring and the magnet, and at the same time with making room for the insertion of the mercoid contact. The upright piece which limits the movement of the free end of the lever in the standard sounder, was changed from position B (see Fig. 2) to position B'. This left the full length of the arm

free to accommodate the mercoid contact, which was held in place with a metal clamp supplied with it, with the contact points toward the fulcrum of the arm. The free end of the arm which no longer reached the upright, was extended by a strip of fiber (*E*) screwed transversely onto its upper surface. The upward movement of the arm was stopped by the contact of the fiber extension with the thumbscrew; while its down-

FIG. 2.



Part of telegraphic sounder, top view. *A*, arm; *B*, upright, in standard key; *B'*, upright, in modified key; *C*, iron crosspiece; *E*, fiber extension; *T*, thumbscrew.

ward movement was stopped before contact of the iron crosspiece (*C*) with the coils of the magnet. When the whole system was connected up with the source of current, the range of movement of the lever was adjusted by the position of thumbscrew *T*, and the tension on the spring was balanced (by means of another thumbscrew) against the strength of the magnet. The switch worked best when the smallest

amount of motion was allowed in the lever which would just shift the mercury back and forth in the mercoid contact.

The chief source of difficulty that was encountered was faulty electrical supply—complete stoppage of current, failure of one phase, over-voltage, etc. Large variations in the voltage on the line (sometimes up to 20 per cent.) destroyed the balance between the tension of the spring and the attractive force of the magnet; and the switch tended to stick in one position or the other. It was under these circumstances that the adjustment of bulbs to the temperature was so useful. With a reliable supply of current, however, the apparatus was perfectly dependable. One more precaution is advisable, if the space in the incubator can be spared—that is, to set up the sounder inside the incubator. It then operates at constant temperature, and is somewhat protected from dust and unofficial handling. However, it can, if necessary, be placed on any secure base outside the incubator. The sounder used for this work should have a high resistance so that the amount of current passing through it does not heat the coils to an appreciable extent. This will also cut down the amount of sparking at the point of contact with the mercury.

Latent Oxygen.—(*Ind. Eng. Chem.*, News Edition 25, 131.) A letter from this magazine's Germany correspondent tells of a powder named "Oxygal" that has recently been brought on the market. This compound contains a relatively large percentage of oxygen chemically combined, yet readily released when needed. The preparation is supplied in air-tight steel-plate containers in which it may be kept indefinitely. For use, it is introduced into a horizontal retort and ignited with a priming mixture, whereupon the evolution of oxygen begins immediately. About 43 per cent. of the material's weight is released as oxygen. In other words one pound of Oxygal will produce 4–8 cubic feet of gas.

No mention is made as to what the chemical formula of the material might be. However, we were much interested to find that potassium chlorate, an old acquaintance of elementary chemistry and a never failing source of oxygen, contains 39 per cent. of this element. Most readers will recall that the white chlorate had to be primed or stimulated by that dirty looking "black oxide of manganese."

In fostering the practical use of their product the manufacturers of Oxygal have constructed a portable oxygen generator in which gas pressures up to 15 atm. can be produced. Two retorts are used so that continuous production is possible.

C.

THE TACTUAL PERCEPTION OF MUSICAL INTERVALS.[1]

BY

LOUIS D. GOODFELLOW, Ph.D.,

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It is common knowledge that vibrations from an orchestra or pipe organ can readily be felt through the floor of the auditorium, and often the movement of the music can be recognized by these vibrations alone. Notable examples are persons deprived of hearing who frequently become so alert to these vibrations that they can keep time to an orchestra or dance very well. Miss Helen Martin, the well-known deaf-blind musician, who spent a year in this laboratory, greatly enjoyed victrola music communicated to her fingers by the Gault Teletactor.[2]

This study is the beginning of a research program to determine (1) the extent to which one can appreciate harmony by means of the sense of touch and (2) the possibility of building a science of harmony on a basis of touch for the benefit of the many deaf lovers of music. Notwithstanding the fact that some observers have been unable to feel vibrations above 2,048 d.v./sec. (C_4) and only a rare observer above 8,192 d.v./sec. (C_6), there are other favorable facts. For example, Roberts[3] found that observers can distinguish two pitches by means of touch if the frequency difference is at least $2\frac{1}{2}$ per cent. of the basic frequency. This paper is a report of the ability of persons to recognize musical intervals by touch.

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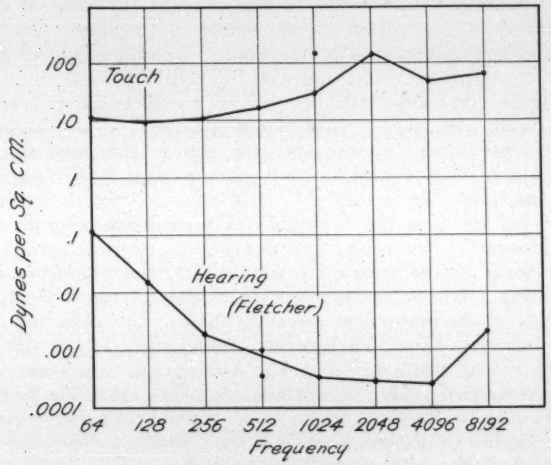
[1] This research was done in the laboratories of Professor Robert H. Gault, to whom the author is indebted for encouragement and many helpful suggestions. It was made possible by the generosity of the Barker Foundation.

[2] This consists of a microphone or electrical pick-up for victrolas, a specially designed amplifier and a powerful vibrator upon which the deaf person places his fingers to feel the vibrations of the speaker's voice.

[3] Roberts, W., "A Two-Dimensional Analysis of the Discrimination of Differences in the Frequency of Vibration by Means of the Sense of Touch," JOURNAL OF THE FRANKLIN INSTITUTE, 213, 285–311, 1932.

The intervals selected to be discriminated by touch were four in number: two consonance [4] (perfect fifth and octave) and two dissonance (minor second and major seventh). They were produced by two trombones chording on various parts of the scale. A series of victrola records was made containing these intervals played in random order, and these records were used throughout the experiment. Twenty normally hearing persons observed. They were all given an

FIG. 1



Sensitivity of the ear and finger-tip.

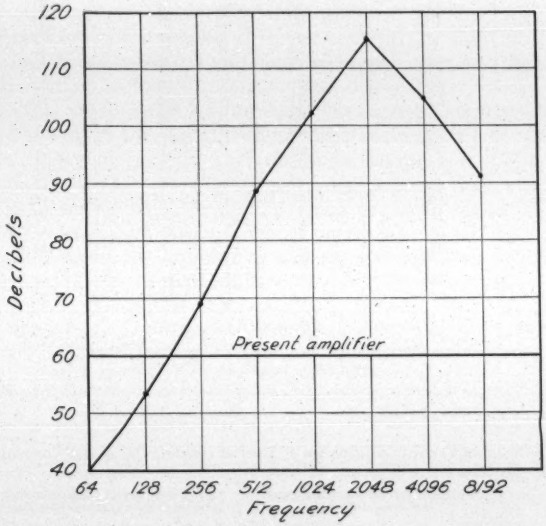
explanation and a demonstration on the piano before the experiment to assure us that they understood the requirements of the experiment perfectly.

A series of sixty intervals arranged in random order was played over the teletactor and each observer tried to identify each interval by its tactual pattern. The sound eliminating

[4] In this paper, for convenience, *consonance* refers to the perfect fifth and octave, and *dissonance* to the minor second and major seventh.

apparatus [5] was used, so that there was no question of any auditory cues entering the experimental situation. The records were then played over the loud speaker, and the observers tried to identify each interval by ear. Table I gives the results of the initial tests for both touch and hearing. These data were scored for both the number of correct

FIG. 2



Amplification needed at each frequency level to compensate for differential sensitivity of touch.

identifications of individual intervals and the number of correct discriminations between consonance and dissonance.

Although correlations of .48 and .53 are low, it is significant that any relation should exist between a person's ability to

[5] The sound eliminating apparatus consists of a double concrete box containing the vibrator, into which a person thrusts his arm in order to feel the vibrations. The effectiveness has been carefully checked, and experimental data to be published in the *Journal of General Psychology* demonstrates clearly that no auditory cues, liminal or subliminal, are operative in the experimental situation.

TABLE I.

Initial Scores Made by Twenty Observers on the Tactual and Auditory Identification of Musical Intervals.

Observer.	Per Cent. Correct Discriminations between Consonance and Dissonance.		Per Cent. Correct Identification of Individual Intervals.	
	Touch.	Hearing.	Touch.	Hearing.
1.....	33	60	13	33
2.....	33	53	13	27
3.....	40	47	23	33
4.....	63	90	27	77
5.....	37	53	23	40
6.....	43	70	23	55
7.....	83	100	40	97
8.....	67	97	35	80
9.....	40	100	24	93
10.....	73	98	38	93
11.....	61	78	31	60
12.....	57	77	32	36
13.....	49	80	21	45
14.....	33	85	17	45
15.....	58	88	22	77
16.....	55	82	23	52
17.....	75	68	32	47
18.....	37	93	22	80
19.....	82	87	43	43
20.....	42	73	22	32
Aver.....	53.0	78.9	26.2	57.2
	$\rho = .48 \pm .12$		$\rho = .53 \pm .11$	

TABLE II.

The Effect on Tactual Identification of Musical Intervals Due to Ear Training.

Observer.	Per Cent. Correct Identification of Individual Intervals.		Per Cent. Correct Discriminations between Consonance and Dissonance.	
	Initial Test.	Test after Ear Training.	Initial Test.	Test after Ear Training.
1.....	13	32	33	82
2.....	13	39	37	70
3.....	23	37	40	70
4.....	23	40	37	65
5.....	23	67	43	75
6.....	32	47	55	84
7.....	17	34	55	68
8.....	23	40	37	75
9.....	43	57	82	93
10.....	22	50	42	73
Aver.....	22.5	44.3	46.1	75.5

identify musical intervals by touch on the occasion of his first experience with the teletactor, and his ability to do the same by ear.

Our next step was to study the effect of ear training on touch. For this, eleven musically untrained persons observed. After the initial test on the teletactor, they were given several half hour periods of ear training [6] and then tested again on the teletactor. Table II shows that in every case an improvement took place and that on the average the scores were raised one hundred per cent. on the identification of individual intervals and over sixty per cent. on the discrimination between consonance and dissonance.

Now we reversed this procedure in order to find the effect of training in the recognition of these intervals by touch on the ability of the ear. Six observers served and, after the regular ear test, were given training in touch. A victrola record containing intervals for which the observer knew the order was played three times at each of three sittings, and at the end of the training period the ear test was repeated. Table III shows that ability to identify these particular

TABLE III.

The Effect of Training in Tactual Identification of Musical Intervals on the Ability of the Ear.

Observer.	Per Cent. Correct Identifications.		Per Cent. Correct Discriminations of Consonance and Dissonance.	
	Initial Test.	Test after Touch Training.	Initial Test.	Test after Touch Training.
1.....	33	63	60	93
2.....	27	68	53	88
3.....	33	60	47	85
4.....	40	75	53	95
5.....	36	46	77	90
6.....	32	52	73	88
Aver.....	33.5	60.7	60.5	89.9

intervals by ear is improved by training in tactual identification—the extent of the improvement being almost fifty per cent. on the discrimination between consonance and disso-

[6] I.e., ear training on these particular intervals.

nance and almost eighty per cent. on the identification of the individual intervals.

In conclusion we may say (1) that musically trained individuals show a tendency to excel the musically untrained on their first attempt to identify musical intervals by touch, (2) that ear training[7] considerably improves one's ability to identify intervals by touch and (3) that training in the tactual identification of musical intervals improves one's ability to identify these intervals by ear.

These data point to the following tentative conclusions:

1. The perception of musical intervals is a central process rather than a function of the receiving sense organ.

2. Through the senses of touch and vibration, one can perceive, at least, two tones sounding simultaneously. Possibly the deaf person (after training) will be enabled to appreciate the harmony of musical compositions which he now enjoys merely because of the rhythm. Furthermore, training in clang analysis and the recognition of chords by the senses of touch and vibration seems to be quite practicable in the light of this research.

3. A very close relationship exists between hearing and the more primitive senses of touch and vibration. Possibly part of our enjoyment of music is a result of vibratory and tactual sensations of which we are unaware.

[7] No implications in relation to intervals other than those used in this study is made.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

HYDRAULIC LABORATORY RESEARCH.

As the result of a proposal made by Doctor Schaffernak of Austria at the World Power Conference at Berlin in 1930, that "an organization be established for the purpose of interchanging, in the field of hydraulic engineering, the results of laboratory research and of observations of natural conditions corresponding thereto," the American committee of the World Power Conference asked the Bureau of Standards last January to serve as the exchange agency for the United States. The object of the proposed organization is to afford promptly to all the hydraulic laboratories throughout the world information as to the nature of the research which each is undertaking, thus permitting a closer coördination of the work. Results will be interchanged long before the final reports are published, and useless duplication of effort will be prevented.

The first step in organizing this service nationally in the United States was to compile and distribute to the hydraulic laboratories in this country a report covering the activities of these laboratories. As a result of the prompt coöperation of the individual laboratories, it was possible for the bureau to issue on April 1, 1933 its first report of this kind, a mimeographed bulletin entitled, "Current Hydraulic Laboratory Research in the United States." The current number gives a history of the undertaking and lists researches in progress in a large number of laboratories. These researches are reported uniformly under nine heads which give the principal facts needed by any one interested in looking up the details of these projects. The second report will be issued on July 1st, and succeeding numbers will appear quarterly.

In addition to the above service, the bureau will compile and issue annually a description of the hydraulic laboratories

* Communicated by the Director.

in the United States, their equipment and facilities for research, insofar as the heads of the laboratories will furnish the necessary information. It is planned to issue the first report of this kind on June 1st.

Those desiring complete information as to this new service should address the Director, Bureau of Standards, Washington, D. C.

STUDIES OF MASONRY CEMENT—FREEZING, THAWING.

The durability of the masonry cement, studied in the general investigation of this material, was determined by recording the number of "freezing and thawing" cycles withstood by each specimen.

The specimens (1" by 4" by 6") were prepared from two mixes; 1 : 3 by weight, using 100 per cent. standard Ottawa silica sand and 1 : 3 by volume using one-third pit run Ottawa sand and two-thirds standard sand. The amount of water added produced normal flow as determined by Federal Specification SS–C–181, F–3g(3)a, b. The curing periods, prior to exposure to freezing and thawing, were 7 and 28 days in a damp closet—temperature 70° F. ± 1, R. H. 98 per cent. Specimens from each mix were made for each curing period. Specimens were made in triplicate for each mix and for each curing period. Forty-one masonry cements were represented by the specimens.

The specimens were placed flat-wise in pans and were one-half submerged in water. Each "freezing and thawing" cycle consisted of placing pans so filled in a freezing chamber at + 14° F. for 17 hours, then transferring the pans to water for 7 hours at room temperature.

Specimens failed in various ways, by spalling, crumbling, and by becoming so soft that they were washed away by the water.

Specimens made from 15 cements are still undergoing freezing and thawing treatment and are in good condition; the average number of cycles being 151. Test pieces from 22 cements failed in less than 10 cycles.

ABRASIVE RESISTANCE OF NATURAL STONE FLOOR TILES.

The demand for data on the wearing qualities of floor surfacing materials has led to a study of several marbles, limestones, etc., that are often used in decorative floors. It was necessary to design a testing machine for the purpose and compare its action with the actual wear on such materials under service conditions. During the past four years a considerable number of materials have been tested for Federal buildings and data have been obtained on a variety of materials. Since there are frequent calls for such information the results have been assembled in a paper for publication. This contains results on 79 marbles, 39 limestones, 22 sandstones, 32 slates, 11 granites, 11 serpentines, 10 travertines, and a few miscellaneous materials that do not fall under the above classification.

A means of expressing the results is employed which gives a simple way of comparing different materials, the numerical values being proportional to abrasive resistance.

The marbles show a considerable range in wear values. The highest result obtained was 41.7 for a fine grained black marble while the lowest, 6.7, was recorded for a rather loose-grained white marble. The average of the 79 marbles was 18.8 which is approximately equal to the values obtained for those marbles that are largely used for floor tile.

The average for 39 limestones was found to be 8.4. This group contained a few materials that would probably not be used in floors except in positions where the traffic is very light. The highest values for any limestones tested was 24.1.

Twenty-two sandstones gave an average of 13.3 and a range from 1.6 to 26.4. The abrasive resistance of this type of material seems to depend largely on the cohesive strength, since the wear results mainly in loosening and removing quartz grains from the surface exposed to abrasion. The highest value obtained for slate was 11.7 while the average was 7.7. The small range in abrasive resistance of this class of material indicates that there is little advantage of one slate over another for flooring purposes.

Although the granites are seldom used for floor surfacing materials they are often used in the approach steps of build-

ings. The ten granites tested showed uniformly high values with an average of 58.

The serpentines find frequent use in floors as decorative strips or inlays. The average of 11 serpentines was found to be nearly as high as that of granites but a large range of values was evident.

The average of ten travertines was found to be 13.7. The travertines used to a considerable extent in floors and steps, gave values somewhat below the average for marble.

The wear values of the different stone now available should prove of special interest to architects in cases where several varieties of tile are combined for color scheme. Past experience has shown that selection based on color alone may lead to undesirable results.

EFFECTS OF VARYING PARTICLE SIZE IN WHITEWARE.

The formation of ceramic whiteware is essentially a process of fusion and of solution which is not permitted to proceed to completion. The process is a function not only of temperature but of the relative surface area of the materials used. The surface area per unit weight may vary considerably for the feldspar and the flint which, together, constitute about 50 per cent. of a ceramic whiteware body and which are ground commercially rather than mined in a finely divided state as is true of clay.

To study the effect of variations in particle sizes of the "raw materials" in whiteware bodies, and the possibilities of reducing manufacturing costs by lowering maturing temperatures, a feldspar and a flint of commercial grade were divided by means of an air elutriator into groups or "fractions" of varying particle sizes.

Various combinations of the several fractions of flint and of feldspar were incorporated in whiteware bodies. Specimens of these bodies were heated at 1,150°, 1,200°, 1,250°, 1,300°, and 1,350° C., and tested for linear shrinkage, porosity, strength in bending and linear thermal expansion. Relative fusion and solution in the body were estimated by microscopic examination.

In bodies containing only 15 per cent. feldspar, varying

the particle size of this ingredient did not greatly affect shrinkage or porosity. However, for bodies containing 25 per cent. feldspar the porosity after heating at 1,200° C., could be reduced from 10 per cent. to practically zero by reducing the size of feldspar particles.

Varying the particle sizes of flint in bodies containing 35 per cent. of this ingredient affected their properties considerably. For example, the porosity of specimens heated at 1,250° could be reduced from 18 per cent. to 3 per cent.

Varying the particle sizes of both flint and feldspar produced the greatest changes in the properties of the bodies. A body containing commercially ground flint and feldspar and having a porosity of 18 per cent. after heating at 1,250° could be vitrified at this temperature when made with flint and feldspar of 10 micron (0.00039 inch) maximum particle diameter.

The data obtained indicate the possibility of vitrifying commercial ceramic whiteware, without the use of auxiliary fluxes, at temperatures significantly lower than are now required in the industry. Further studies of the effects of particle size of flint and feldspar in ceramic whiteware bodies, particularly with regard to the development of bodies which can be used advantageously on a commercial scale, are believed justified.

GLASS PHASE IN FIRED CLAY MATERIALS.

At the Columbus station, in the study of the glass phase in fired clay materials, a number of glasses have been prepared in the four-component system $K_2O.CaO.Al_2O_3.SiO_2$. The surfaces of the tetrahedron representing this system are composed of the following three-component systems: $K_2O.Al_2O_3.SiO_2$, $CaO.Al_2O_3.SiO_2$, $K_2O.CaO.Al_2O_3$, and $K_2O.CaO.SiO_2$, all of which are of ceramic importance. Glasses whose compositions are represented by points within the tetrahedron are formed whenever mixtures such as flint, feldspar, whiting, and china clay are subjected to high temperatures. A knowledge of the properties of all these glasses in the tetrahedron would be of considerable value to ceramists.

At present the portion of the tetrahedron lying between the 50 per cent. and 80 per cent. silica levels is being investigated. A preliminary study, using cones, was made to obtain some idea of the fluidity of these glasses. The raw materials used were potters' flint, calcium and potassium carbonates, and hydrated alumina. Two fusions were made of mixtures of these raw materials in the proper proportions. Each fusion was followed by a fine grinding of the mass in order to produce a homogeneous glass. The pulverized glass was then moistened with a solution of gum and molded into standard sized cones. These were fired in a muffle furnace and the temperatures at which they deformed were noted. Two refractory areas were found in the 50 per cent. silica level: one at 20–25 per cent. K_2O, 5–10 per cent. CaO and 15–25 per cent. Al_2O_3; and the other at 5 per cent. K_2O, 15 per cent. CaO and 30 per cent. Al_2O_3. Two low melting areas, one high potash low alumina, the other at 5 per cent. K_2O, 20 per cent. CaO and 25 per cent. Al_2O_3, were found. Both the refractory and the low-melting regions extended (as volumes) up to the 60 per cent. silica levels.

Those glasses were selected for further study which were not (1) too refractory to be fired at a temperature limited by the deformation of the container, a high alumina clay crucible, nor (2) too corrosive due to high lime content, nor (3) too hygroscopic due to high potash.

BLIND LANDING OF AIRCRAFT.

The theory of operation and use of the radio system of landing aids now under service test at the Newark Municipal Airport, Newark, N. J., was outlined in Technical News Bulletin No. 192 (April, 1933). Since March 15, the practicability of the system has been demonstrated by numerous landings in a hooded cockpit and also under fog conditions which interrupted all scheduled flying over a widespread area including the Newark airport. The tests included a completely blind flight in dense fog from College Park, Md., to Newark Airport during which the ground was entirely hidden until the plane was within about 2,000 feet of Newark Airport at an altitude of somewhat over 100 feet. The results of the numerous demonstrations and tests at Newark corrobo-

rate performance data on the complete system accumulated during the experimental work at College Park. The precision of the system there developed has proved to be more than sufficient for the actual requirements of practical use at Newark.

Because of obstructions in the approach at College Park it was found necessary to provide a very precise and sharp runway localizing course. The transmitting and receiving equipments were so adjusted that, at five miles from the beacon, a deviation from the course of approximately 200 feet could readily be detected, while at a distance of one-half mile, a deviation of 20 feet was easily discernible. At a distance of 4,000 feet, corresponding to the approach end of the field at Newark Airport, a deviation of 30 feet is noticeable. The runway at Newark is 500 feet wide. The actual path of the beacon course was checked at College Park periodically over a long interval and found to be fixed regardless of weather conditions and ground conductivity. To utilize the course sharpness available it was necessary to adopt a directional receiving antenna on the airplane which compensated automatically for a tendency to "weave" or "hunt" about the course and thus facilitated holding accurately to the course. The desired compensation was secured through the addition of an inclined wire running from the top of the vertical pole antenna back to the rudder fin.

Obstructions in the approach at College Park also necessitated close control of the landing path. Thus, it was necessary to clear a house chimney, approximately 1,500 feet from the edge of the field, by about eight feet. The necessary fixed landing path was obtained by maintaining approximately constant power output at the landing beam transmitter and through the use of a landing beam receiving set having nearly constant amplification under all operating conditions. Calculation of the landing path at Newark shows that a drop of 10 per cent. in power output would raise the landing path, while an equal rise in power would lower it. At three miles from the landing beam transmitter, a change of 10 per cent. in power would result in a change of about 30 feet in an altitude of 630 feet, while at two miles, the change in altitude would be about 15 feet in an altitude of 280 feet. Over the

far marker beacon it would be about six feet in an altitude of 100 feet, and over the boundary marker beacon, about four feet in 45 feet. These calculations have been verified experimentally. Experience indicates that, in practice, the output power of the landing beam transmitter can be readily maintained to within plus or minus 5 per cent., so that the resultant change in steepness of the landing path will be negligible.

The effect of variation in the constancy of amplification of the landing beam receiving set upon the landing beam path is about double that given in the foregoing for transmitter power variation; i.e., a 10 per cent. change in the receiving set sensitivity produces twice the change in the landing path that results from a 10 per cent. change in the transmitter power. A simple receiving set has been designed at the Bureau of Standards for this service. Its sensitivity remains constant to within a few per cent. for all changes in applied voltages, aging of tubes and other component parts. The sensitivity is constant for all filament voltages from 10 to 15 and for dynamotor supply voltages from 100 to 250. The variation of amplification with the life of a tube is negligible until the tube begins to lose emission. Reasonably frequent checking of the landing beam receiving set is therefore all that is necessary to insure a proper landing path. Once the landing path for a given airplane has been adjusted by means of the glide angle adjustment, this adjustment should be locked and the corresponding receiving set sensitivity measured. This is done through the use of a signal generator which is connected to the input terminals of the receiving set and the output voltage of which is varied until the "on-course" deflection is obtained on the horizontal pointer of the "combined instrument." The voltage corresponding to this deflection is then employed as a standard to which the receiving set is adjusted in future checks.

The results at Newark, where the landing path remained entirely constant for the past two months under a wide variety of weather conditions, confirms the foregoing data, particularly since not even a minor adjustment of the landing beam transmitter or of the landing beam receiving sets on the two test airplanes was required.

PHOTOELASTIC STUDY OF RUBBER.

When transparent rubber is stretched, it exhibits the well-known phenomenon of double refraction. A study is being made of the double refraction of rubber as a function of the stress and the composition. The measurements cover the range of stresses from 1 to 100 bars (the bar is a unit of pressure, equal to 14.50 lbs./in.^{2}), which correspond, for the samples employed, to elongations from about 20 to 600 per cent. One rubber compound which was studied in some detail was made according to the following formula:

	Parts by Weight
Pale crepe rubber	100.0
Zinc oxide (Kadox)	1.0
Stearic Acid	1.0
Sulphur	2.0
Tetramethylthiuramdisulphide	0.3
	104.3

In order to ascertain the effect of the sulphur content on the photoelastic behavior of rubber, similar compounds were made with 4, 5, and 6 per cent. of sulphur, respectively, but without the tetramethylthiuramdisulphide.

The measurements are expressed in terms of the stress-optical coefficient in brewsters. A coefficient of one brewster signifies that when a beam of light is passed through the substance rendered doubly refracting by the stress, the extraordinary ray is retarded 1 Angstrom unit behind the ordinary ray when the thickness of the sample is 1 millimeter and the stress is 1 bar. Thus the brewster is 10^{-13} cm.^{2} dyne^{-1}. The double refraction at any value of the stress is related to the stress-optical coefficient, C, by the equation,

$$n_0 - n_e = 10^{-7}CS,$$

where n_0 and n_e are the refractive indices for the ordinary and the extraordinary rays, respectively, and S is the stress in bars.

Since the refractive indices, and hence the stress-optical coefficient, may vary with the wave-length of the light, all measurements were made with monochromatic light of wave-length 5,461 Å. U. obtained from a mercury arc.

The stress-optical coefficient for the accelerated rubber compound of the formula given above is about 2,000 brewsters

at a stress of 2.5 bars (elongation, 20 per cent.), and increases to 2,100 brewsters at 13 bars (elongation, 110 per cent.) and remains constant within the probable experimental error of ± 10 brewsters up to a stress of 55 bars (elongation, 330 per cent.). At higher stresses rubber of this composition exhibits optical creep. The compounds which were vulcanized with sulphur alone, without the organic accelerator, do not show a similar constancy of the stress-optical coefficient with varying elongation. The values for the coefficient range from 2,000 to over 3,300 brewsters and appear to be a function of both the stress and the sulphur content.

Inasmuch as stress-optical data may not be familiar to investigators in other fields, it may be of interest to note that the coefficient for rubber is high in comparison with coefficients for most other transparent materials. Inorganic crystalline substances and glasses have coefficients in the range 1 to 5 brewsters, celluloid has a coefficient of about 10 brewsters, and bakelite, a coefficient of about 50 brewsters. Gelatines, however, have coefficients of 5,000 to 20,000 brewsters and are the only common materials higher than rubber in this respect.

EFFECT OF TEMPERATURE ON LITHOGRAPHIC PAPERS.

Further information has been obtained at the bureau to assist lithographers in overcoming misregister of successive color prints, which is the most prolific source of waste in the industry.

Five samples of lithographic papers, representative of the different types of papers most commonly used in offset printing, have been studied at eight different temperatures, ranging from 68° to 110° F. Dimension changes, the most common cause of misregister, were determined by measuring specimens approximately 24 by 24 inches to 0.001 inch, and moisture content changes were determined by weighing somewhat smaller samples on a chemical balance to 0.0001 gram. The relative humidity was maintained constant at 45 per cent. throughout so that the temperature was the only factor varied.

The temperature changes resulted in regular moisture content changes, the average change being 0.2 per cent. per

10° F. temperature change for the five papers studied. The moisture content varied inversely with the temperature, that is, the moisture content of the paper went down as the temperature went up and increased as the temperature fell.

All changes in moisture contents of the papers were accompanied by proportionate dimensional changes. The same relationship between moisture content and dimensions was found to exist as when moisture content changes resulted from humidity variations, and a single smooth curve was obtained when plotting moisture contents against dimensions with both temperature and relative humidity varied. Therefore it appears that the dimensions of such papers vary directly with moisture content regardless of whether moisture content changes result from variations in relative humidity or temperature, at least within the range ordinarily encountered. Temperature changes had the same effects on the papers as relative humidity changes except that they were of different magnitude and in the reverse order. For example, in the vicinity of 45 per cent. relative humidity, the papers were affected in the same manner and to approximately the same extent by an increase in temperature of 40° F. as by a decrease in relative humidity of 9 points.

AIR PERMEABILITY OF PAPER.

Considerable attention is being devoted at the bureau to precise measurement of air permeability of paper. The rather large differences in the facility with which different kinds of paper permit the passage of air are significant in a great many ways. The effectiveness of sheathing paper used in the walls of houses depends upon their air-tightness in order to minimize heat losses from infiltration. Many food products are incased in airtight wrappers to prevent the absorption of objectionable odors and to preserve the freshness of the food. A certain degree of resistance to permeation of air is necessary in cigarette paper to insure the proper draft through the burning tobacco. Air permeability and dielectric strength are intimately related in electric cable insulation. Air permeability is more or less intimately related with the rate of absorption of organic liquids in the

case of saturating felts or paper (for making roofing, treated wrappers, cable insulation, bakelite), in printing papers, and in greaseproofed papers. In addition to these direct applications, air permeability is an extremely important tool in the study of the structure of paper and in determining the relation of pore space to other properties of paper and fibrous sheet materials.

Nearly a score of air permeability measuring devices have been described in the literature, a few of which have been used rather extensively. A preliminary experimental study has been made at the bureau of such of these as were available. Although some of these testing devices are suitable for the ordinary requirements in testing certain kinds of paper, none of them adequately fulfills the requirements of a reference standard, since they are not adapted to cover the large range of air permeability represented by paper and boards in general, and since the uncertainty in the measurement is often rather large. Perhaps the chief source of uncertainty is in leakage in the apparatus or at the edges of the specimen, and the absence of simple means of detecting such leakage. Instances were found in which the error from leakage was as great as the air permeability itself. Some other deficiencies noted are: Small testing area, inconstancy of driving pressure, lack of sensitivity, and length of time required to test papers of low permeability. After making the preliminary survey it seemed advisable to design a new instrument suited to precision testing and adapted to accommodate practically any kind of paper or fiber board and this work is now in progress.

NOTES FROM THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

THE AZIMUTHAL ASYMMETRY OF THE COSMIC RADIATION IN MEXICO CITY.*

BY

THOMAS H. JOHNSON.

The theory of the motion of electrically charged particles in the magnetic field of the earth has been developed, in relation to the cosmic ray problem, by Le Maitre and Vallarta. The theory predicts that in those latitudes where the intensity is varying, electrically charged corpuscular rays should be found, striking the earth only within limited angular regions, the boundaries of which are defined by the energy and mass of the corpuscles in relation to the magnetic moment and radius of the earth and the latitude. These limited angular regions are of such a character that they open up for positive particles first from the west.

Compton's analysis of his intensity measurements, on the basis of the Le Maitre-Vallarta theory, indicates the existence of an energy band of corpuscular rays of such an energy that the east-west differences in intensity should be the greatest in intermediate latitudes. With this prediction in mind, measurements have been made in Mexico City in geomagnetic latitude 29° N and at an elevation 2250 meters above sea level. Two independent sets of Geiger-Mueller counters were used as triple-coincidence-counting telescopes and the measurements were made in such a way as to most effectively compare the east and the west intensities at the same angles from the vertical. Since the total intensity varies rapidly with the angle from the vertical it was necessary to be quite certain that this angle was exactly the same in both azimuths. For this reason changes in azimuth were made by rotation about a vertical axis and any possible differences between the true angle and the measured angle were thus the same in

* Paper for the Washington Meeting of the American Physical Society.

both azimuths. Each comparison of the two intensities was the result of about forty counting periods alternating between the two azimuths. The probable errors could therefore be estimated from the dispersion of the data as well as be calculated from the total number of counts by statistical theory. In practically all of the measurements the agreement between the estimated and the theoretical probable errors was satisfactory, indicating the absence of any sources of error other than the statistical nature of the phenomenon itself.

THE FIRST SLIDE.

In the first slide the counting rates in the east and the west azimuths have been plotted for various angles from the vertical, the east rates being represented by the circles and the west rates by the crosses. The upper pair of curves was obtained with instrument number one and the lower pair with instrument number two. In every case within the angular range 30° to 55° the west intensity was greater than that of the east, the order of magnitude of the difference being 10 per cent.

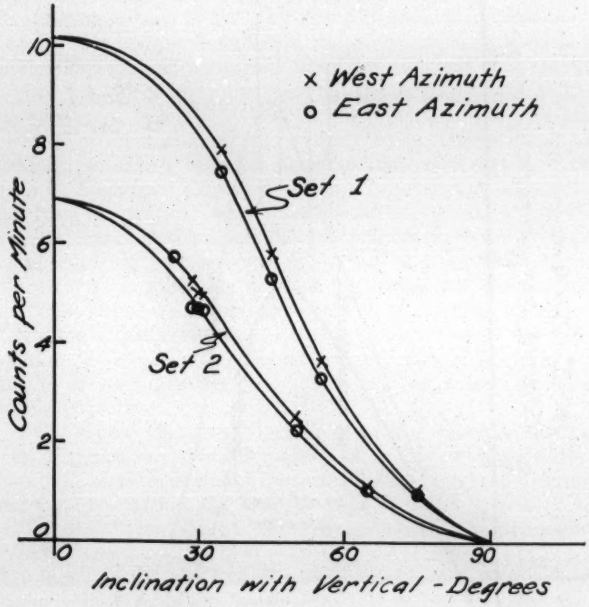
THE SECOND SLIDE.

In the second slide are plotted the west-east differences with the estimated probable errors indicated by the vertical lines. In this figure the crosses and circles represent data taken by instruments No. 1 and No. 2 respectively. The west-east difference increases with the angle from the vertical up to 45° or 50° and then it falls sharply to a low value at angles greater than 60°. In the case of some of the measurements the difference in the intensities of the two azimuths was more than six times the probable error. *The results therefore seem conclusive in showing the existence of an azimuthal asymmetry in the radiation of the type predicted by the theory of the latitude effect,* and *a very important result of the measurements is the fact that the greater west intensity shows that the principal component of the corpuscular radiation in the energy range from* 1.10^{10} *to* 2.10^{10} *volts is positively charged.*

The small value of the intensity differences at angles below 65° is to be attributed to the stopping of the oblique rays by the atmosphere. Evaluating the energy of these rays from the Le Maitre-Vallarta theory we arrive at the

conclusion that these corpuscular rays lose energy at the surprisingly high rate of 1×10^9 volts per meter of water. This value, however, is in close agreement with the fact that no latitude variations are observable outside of the 40° equatorial belt.

FIG. 1.

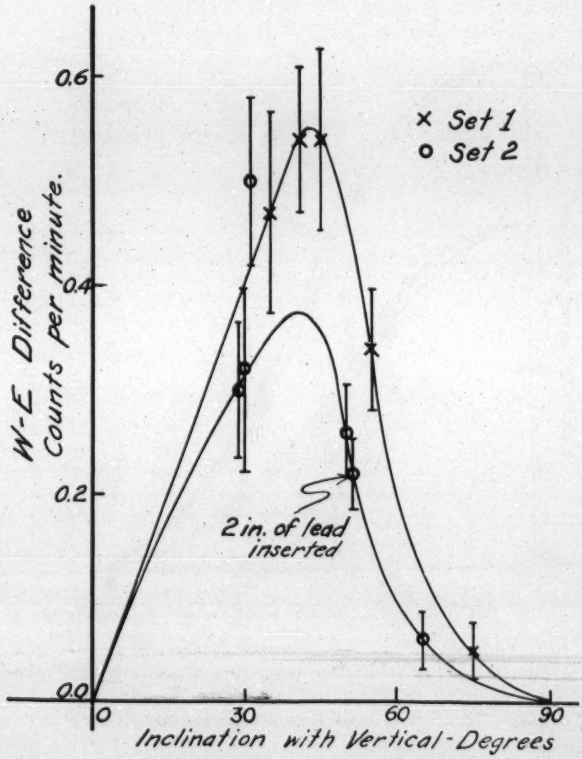


One run at 50° from the vertical was made with 2 inches of lead inserted between the counters. In agreement with the expectations the lead had no appreciable effect on the east-west difference.

A run at 45° from the vertical compared the intensities in the four principal azimuths, N., S., E. and W. Within the probable error which was of the order of one-sixth of the E.-W. difference, the N., S. and W. azimuths were of equal

intensity and the east intensity was 7 per cent. lower than the other three. This condition of equal intensities in all but a region to the east of the meridian can be deduced from

FIG. 2.



the theory on the assumption of a uniform distribution of energies in the band from $x_0 = .33$ to 0.80 corresponding to electron energies from 6 to 38×10^9 volts. This finding

therefore cannot be taken as an argument in favor of a band of discrete energies although it is not inconsistent with Compton's deduction of a band with an upper limit at $x_0 = 0.45$. For the purpose of resolving a band at this energy, the latitude of Mexico is unfortunate and measurements should be made somewhat further south.

The magnitude of the west-east difference is a measure of the number of rays included in the range of energy between that which is just permitted from the east and that which is just excluded from the west at the angle at which the measurement is made. Compton deduces that the latitude effect is to be accounted for entirely by an energy band of uniform intensity between $x_0 = .30$ and $x_0 = 0.45$. Since rays in the upper two-thirds of this band should appear at 50° from the vertical in the west but not in the east, the west-east difference at this angle should have a ratio to the average total counting rate equal to about one and one-third times the ratio of the difference between the intensity at the equator and that above the forty degree parallel to the total intensity. Compton's deduction would therefore give rise to the prediction of an east-west difference of the order of 30 per cent. of the average counting rate. This is about three times the observed value.

One would therefore conclude from this evidence that, if the corpuscular radiation consists of positive charges alone, not more than one-third of the latitude effect can be accounted for by rays within the energy range between $x_0 = 0.37$ to $x_0 = 0.48$. This possible discrepancy between the *interpretation* of Compton and these results, however, should not mask the fact that the two sets of experimental results, themselves, seem to be in excellent agreement.

In conclusion, although the results obtained with Dr. Street on Mt. Washington in a similar manner last September and reported at the Atlantic City Meeting gave only an indication of an azimuthal asymmetry, the E.-W. differences being only of the order of twice to three times the probable error, yet it is worthwhile noting that the present results are completely in agreement with those indications both as regards the fact of a lower intensity in the east and as regards the uniformity of the intensity in the other directions.

For the Nickel and Monel Metal Finisher.—Those having a problem regarding the grinding, polishing and buffing of these two metals may consider their troubles at an end—almost ended at least. A large producer of nickel and monel metal has recently issued a technical bulletin covering in considerable detail the various methods for finishing objects fabricated from the two metals. Directions are given on how to properly make up the grinding and polishing wheels. The properties and applications of various polishing and buffing compounds are described and many specific examples of finishing are included.

C.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, MAY 17, 1933.

The stated monthly meeting of the Institute was called to order at three-thirty P.M. by the President of the Institute, Mr. Nathan Hayward.

The Chairman stated that the minutes of the April meeting had been printed in full in the May number of the JOURNAL of the Institute and that, if there were no objections, the minutes would stand approved as printed. No objection was uttered and the minutes were declared approved.

The Chairman then stated that the next business of the meeting was the presentation of medals which had been recommended by the Committee on Science and the Arts and voted by the Board of Managers throughout the past year. Certificates of Honorary Membership were also presented.

The order of awards proceeded as follows:

PROGRAMME.

	Sponsors
Presentation of a Certificate of Honorary Membership to	
ALFRED RIGLING Philadelphia, Pennsylvania	Dr. Howard McClenahan
Presentation of Certificate of Merit to	
HENRY SELBY HELE-SHAW, D.Sc., LL.D., F.R.S. London, England	Dr. T. K. Cleveland
ARTHUR F. POOLE Ithaca, New York	Mr. Charles E. Bonine
Presentation of Longstreth Medals to	
HOWARD L. INGERSOLL New York Central Lines New York City, New York	Mr. Benjamin Franklin
DUNLAP JAMISON MCADAM, JR., PH.D. Bureau of Standards Washington, D. C.	Mr. G. H. Clamer
Presentation of Wetherill Medals to	
HENRY S. HULBERT, FRANCIS C. MCMATH AND ROBERT R. MCMATH The McMath-Hulbert Observatory, University of Michigan Lake Angelus, Michigan	Mr. James Stokley
INDUSTRIAL BROWNHOIST CORPORATION Bay City, Michigan	Mr. Robert L. Wood
THE KOPPERS COMPANY OF DELAWARE Pittsburgh, Pennsylvania	Mr. Owen B. Evans

Presentation of Levy Medal to
LEON S. MOISSEIFF, C.E. — Dr. Winthrop R. Wright
New York City, New York

Presentation of Henderson Medal to
OTHO C. DURYEA — Mr. M. M. Price
O. C. Duryea Corporation
New York City, New York

Presentation of Potts Medal to
IGOR I. SIKORSKY — Mr. Henry B. Allen
Sikorsky Aviation Corporation
Bridgeport, Connecticut

Presentation of Cresson Medal to
JUAN DE LA CIERVA — Mr. John B. Klumpp
London, England

Presentation of the Franklin Medal and Certificate of Honorary Membership to
PAUL SABATIER, D.Sc., Dean — Dr. James Barnes
Faculty of Science
Toulouse University
Toulouse, France
Received by Monsieur Andre de la Boulaye, Ambassador of France to the United States

Presentation of the Franklin Medal and Certificate of Honorary Membership to
ORVILLE WRIGHT, DR. TECH. SCI., D.ENG., D.Sc., LL.D. — Dr. James Barnes
Dayton, Ohio

The President then declared the meeting adjourned, at four-thirty P.M.

HOWARD MCCLENAHAN,
Secretary.

(An extended account of the proceedings of this Medal Day meeting will appear in an early issue of the JOURNAL.)

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, May 10, 1933.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, MAY 10, 1933.

MR. THEOBALD F. CLARK *in the Chair.*

The following report was presented for final action:

No. 2959: Continuous Automatic Train Stop and Automatic Cab Signal System.

This report recommended the award of the Elliott Cresson Medal to the Union Switch and Signal Company, of Swissvale, Pennsylvania, "In consideration

of the merits of the inventions embodied in the code system of the continuous automatic train stop and the automatic cab signal system which, in combination, serve to promote safety of railroad travel and at the same time to increase traffic capacity."

The following reports were presented for first reading:

No. 2965: Method of Producing Low Cold Test Lubricating Oils.

No. 2970: Synchronous Free Pendulum Clock.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May 24, 1933.*)

Elections.

RESIDENT.

MR. CYRIL LEVER, Chemist, W. H. Burns Company, Philadelphia, Pa. For mailing: 503 Rodman Avenue, Jenkintown, Pa.

NON-RESIDENT.

MR. EDWIN R. MAURER, Auto Research Engineer, Chrysler Corporation, Detroit, Michigan. For mailing: 7358 Kipling Avenue Detroit, Michigan.

CHANGES OF ADDRESS.

MR. CHESTER LESLIE DAVIS, Patent Department, Radio Corporation of America, 832 Washington Building, Washington, D. C.

MR. LOUIS A. FLANAGAN, 405 Cinnaminson Street, Riverton, New Jersey.

MR. JOHN J. GIBSON, "Red Gables," Dogwood Lane, Rye, New York.

MR. WILLIAM MELAS, 176 Edgehill Road, Bala-Cynwyd, Pa.

MR. ARTHUR F. POOLE, 305 Parkway, Ithaca, New York.

MR. FREDERIC ROSENGARTEN, 1520 Locust Street, Philadelphia, Pa.

DR. GEORGE D. ROSENGARTEN, Malvern, Pa.

MR. VICTOR H. SEVERY, 2717 Angus Street, Los Angeles, California.

MR. CLIFFORD J. SUMMERS, 5127 Winthrop Avenue, Chicago, Illinois.

MR. CHARLES A. YOUNG, Northeast High School, Eighth Street and Lehigh Avenue, Philadelphia, Pa.

MR. A. RAYMOND WHITE, 11443 South Union Avenue, Chicago, Illinois.

LIBRARY NOTES.

RECENT ADDITIONS.

ADAMS, MARY, Editor. Science in the Changing World, by Thomas Holland, H. Levy, Julian Huxley, John R. Baker, Bertrand Russell, Aldoux Huxley, Hugh I'A. Fausset, Hilaire Belloc, J. B. S. Haldane, Oliver Lodge. 1933.

AITCHISON, LESLIE, AND WILLIAM R. BARCLAY. Engineering Non-Ferrous Metals and Alloys. 1923.

American Gas Association. Fourteenth Annual Convention, 1932—Proceedings.

American Institute of Electrical Engineers. Transactions. Volume 52, No. 1, March 1933.

American Public Health Association and American Water Works Association. Standard Methods for the Examination of Water and Sewage. Seventh edition. 1933.

BELL, A. H. The Exponential and Hyperbolic Functions and their Applications: a Practical Book for the General Student and Engineer. 1932.

BÖMER, A., A. JUCKENACK, AND J. TILLMANS. Handbuch der Lebensmittelchemie. Erster Band: Allgemeine Bestandteile der Lebensmittel. Ernährung und allgemeine Lebensmittelgesetzgebung. 1933.

CHAFFEE, E. LEON. Theory of Thermionic Vacuum Tubes. Fundamentals—Amplifiers—Detectors. First edition. 1933.

CROCKER, FRANCIS B., MORTON ARENDT, AND RAY F. KUNS. Storage Batteries. A Practical Presentation of the Principles of Action, Construction, and Maintenance of Lead and Non-Lead Batteries and their Principal Commercial Application. 1933.

DORÉE, CHARLES. The Methods of Cellulose Chemistry, Including Methods for the Investigation of the Compound Celluloses. 1933.

DRUCKER, C., UND E. PROSKAUER. Physikalisch-chemisches Taschenbuch. Unter Mitwirkung zahlreicher Fachgenossen. Bd. 1–2. 1932–1933.

EBERHARD, G., A. KOHLSCHÜTTER, UND H. LUDENDORFF. Handbuch der Astrophysik. Bd. V.: Das Sternsystem, erster Teil. 1933.

ETCHEVERRY, B. A., AND S. T. HARDING. Irrigation Practice and Engineering. Volume I: Use of Irrigation Water and Irrigation Practice. Second edition. 1933.

FRANKLIN, BENJAMIN. The Complete Works in Philosophy, Politics, and Morals of the Late Dr. Benjamin Franklin, Now First Collected and Arranged with Memoirs of his Early Life, Written by Himself. In three volumes. 1806.

GREAVES, RICHARD HENRY, AND HAROLD WRIGHTON. Practical Microscopical Metallography. Second edition, revised and enlarged. 1933.

HATHAWAY, KENNETH A. Television. A Practical Treatise on the Principles upon which the Development of Television Is Based. 1933.

Institute of British Foundrymen. Proceedings. Volume XXV, 1931–1932.

KAMM, OLIVER. Qualitative Organic Analysis. An Elementary Course in the Identification of Organic Compounds. Second edition. 1932.

LEWIS, ROBERT S. Elements of Mining. 1933.

(London) Metropolitan Water Board. Twenty-ninth Annual Report for the Year Ended 31st March, 1932. No date.

MAXIM, HIRAM PERCY. Life's Place in the Cosmos. 1933.

NORD, F. F., UND R. WEIDENHAGEN. Ergebnisse der Enzymforschung. Band 1. 1932.

PLANCK, MAX. Wege zur physikalischen Erkenntnis. Reden und Vorträge. 1933.

PLANCK, MAX. Where is Science Going? With a Preface by Albert Einstein. Translated and Edited by James Murphy. 1933.

Royal Society of Edinburgh. Transactions. Session 1932–33. Volume LVII, Part 2. 1933.

STANSEL, N. R. Industrial Electric Heating. 1933.

STETTBACHER, ALFRED. Die Schiess-und Sprengstoffe. Mit einem Anhang: Die chemischen Kampfmittel. Zweite, völlig umgearbeitete Auflage. 1933.

STINY, JOSEF. Die Quellen. Die geologischen Grundlagen der Quellenkunde für Ingenieure aller Fachrichtungen sowie für Studierende der Naturwissenschaften. 1933.

Sugar Reference Book and Directory 1932–33.

THAYSEN, A. C., AND H. J. BUNKER. The Microbiology of Cellulose, Hemicelluloses, Pectin and Gums. 1927.

WÜRZNER, ERICH. Benzingewinnung aus Braunkohle durch Schwelung und Spaltung. 1933.

BOOK REVIEWS.

DONNÉES NUMERIQUES DE PHOTOGRAPHIE. Redigeés par Dr. W. Clark, Eastman Kodak Company, Rochester, et L. P. Clerc, Faculté des Sciences, Paris. Extract from Volume VIII, 1927–1928, of the annual tables of constants and numerical data on chemistry, physics, biology and technology, published under the patronage of the International Council on Research and the International Union on Chemistry, pure and applied. xxi–32 pages, 22 × 28 cms., boards. Paris, Gauthier-Villars, and New York, McGraw-Hill Book Company, Inc., 1932. Price $1.56.

The use of the photographic plate as a detector and recorder of radiant energy has become an important adjunct in investigations which involve visible or invisible radiations. Since the classic experiments of Hurter and Driffield, sensitometry has made progress in the coördination of theoretical data with the results of quantitative experiment. A large amount of numerical data on the methods of sensitometry and their application to currently available photographic materials has therefore become available from many scattered sources.

The present extract is, in the main, a bibliography of important papers which appeared during 1927 and 1928. Many of the references are accompanied by short abstracts, and in some cases by abstracts of considerable length. A feature which will be appreciated in this country is the juxtaposed English translation with the French text. The editors point out that the numerical values which are given apply strictly only to the specimens used in the experiments reported. These coefficients therefore can indicate the order of magnitude only.

The volume should prove of material value to those interested in sensitometric processes and the materials to which they are applied.

L. E. P.

HOMMAGE A HENRI MOISSAN. Memorial volume of the celebration at Meaux, October 4th, 1931, on the occasion of the dedication of a monument to the memory of Henri Moissan. 93 pages, plates, 23 × 28 cms., paper. Paris, Chimie et Industrie, 1932.

The life story of Henri Moissan has often been told. The memory of his life work will long command the admiration of men of science, no less by the usefulness of his achievements than by the numerous occasions upon which they have proved a *honoris causa*. The list of his published investigations is impressive.

Until his isolation of fluorine, that elusive element had defied all the efforts of famous predecessors for its preparation in a pure state. In the early nineteen hundreds, Moissan's electric furnace became the cradle of present-day large-scale electro-thermic operations. Little can be added to professionally honor the memory of this resourceful and indefatigable investigator in the estimation of the world of science. Yet some tangible device has been demanded by his numerous friends in his own country and in many others that may appeal to the commonplace wayfarer as well as to the man of science—a monument in his home town. The project received active and generous support locally and internationally. Unveiling ceremonies at Meaux, organized by the initiative of the Societe de Chimie Industrielle, took place on the 4th of October, 1931.

The present commemorative volume includes a narrative of the life and work of M. Moissan, a chronological list of his scientific papers and other publications (1874–1907), an account of the unveiling ceremonies, and verbatim reports of the addresses of local and visiting delegates. Lists follow of the personnel of French and foreign delegations, and of the contributors to the execution of the monument.

The volume with its fine engravings of M. Moissan in his laboratory, the monument and other objects and scenes of interest in the proceedings, as well as the superior typography, constitute a souvenir of the famous chemist which should have an honored place in a scientific library.

L. E. P.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 452. General Potential Theory of Arbitrary Wing Sections, by T. Theodorsen and I. E. Garrick, 35 pages, tables, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1933. Price ten cents.

This report gives an exact treatment of the problem of determining the two-dimensional potential flow around wing sections of any shape. The treatment is based directly on the solution of this problem as advanced by Theodorsen in N. A. C. A. Technical Report No. 411. The problem condenses into the compact form of an integral equation capable of yielding numerical solutions by a direct process.

An attempt has been made to analyze and coördinate the results of earlier studies relating to properties of wing sections. The existing approximate theory of thin wing sections and the Joukowsky theory with its numerous generalizations are reduced to special cases of the general theory of arbitrary sections, permitting a clearer perspective of the entire field. The method not only permits the determination of the velocity at any point of an arbitrary section and the associated lift and moments, but furnishes also a scheme for developing new shapes of preassigned aerodynamical properties. The theory applies also to bodies that are not airfoils, and is of importance in other branches of physics involving potential theory.

Report No. 454. Photomicrographic Studies of Fuel Sprays, by Dana W. Lee and Robert C. Spencer, 27 pages, plates, 23 × 29 cms., Washington, Superintendent of Documents, 1933. Price ten cents.

A large number of photomicrographs of fuel sprays were taken for the purpose of studying the spray structure and the process of spray formation. They were

taken at magnifying powers of 2.5, 3.25, and 10, using a spark discharge of very short duration for illumination. Several types and sizes of nozzles were investigated, different liquids were used, and a wide range of injection pressures was employed. The sprays were photographed as they were injected into a glass-walled chamber in which the air density was varied from 14 atmospheres to 0.0013 atmosphere.

Within the range investigated, the photomicrographs support the theory advanced by Dr. R. A. Castleman, Jr., to explain the atomization of liquid fuels in carburetors and in injected sprays. With injected sprays, the fuel leaves the nozzle as an unbroken column, is ruffled, and then torn into small, irregular ligaments by the action of the air. The ligaments are then quickly drawn up into drops by the surface tension of the fuel. Turbulent fuel flow accelerates the disintegration of the fuel jet by ruffling its surface close to the orifice, but has relatively small disintegrating power in itself. When other factors are kept constant the degree of disintegration of the jet increases with the distance from the nozzle, the air density, the fuel velocity, or the fuel turbulence, but decreases with an increase of fuel viscosity, surface tension, or nozzle orifice diameter.

R.

MICROENERGETIQUE, Tome II. Les Theorie et les Faits, par Pierre Bricout, Docteur es Sciences, Repetiteur a l'Ecole Polytechnique. iv–429 pages, 16.5 × 25 cms., paper, Paris, Gauthier-Villars, 1933. Price 100 francs.

The second of the two volumes of this notable work now appears. The first of the two volumes which was recently noticed in these pages is introductory in character. It contains in part I a review of the mathematical devices which are specially applicable to the analysis of the properties of atomic structure, and, in part II, a discussion of the fundamental facts of atomic physics upon which is based the synthetic development of their applicable theory.

The present volume embraces a third and fourth part. Part III deals with the principles of wave and quantum mechanics. Part IV proceeds to the application of the theorems previously developed to phenomena only satisfactorily explained by a consideration of atomic properties.

In relatively small compass, in this work Professor Bricout has provided means for the mathematical reader to achieve a rational understanding of the intricacies of the mechanics of the modern atom.

L. E. P.

PUBLICATIONS RECEIVED.

The Physiological Effects of Radiant Energy, by Henry Laurens, 610 pages, tables, illustrations, 15.5 × 23.5 cms. New York, Chemical Catalog Co., Inc., 1933. Price $6.00.

Traveling Waves on Transmission Systems, by L. V. Bewley, 334 pages, tables, illustrations, 15.5 × 23.5 cms. New York, John Wiley & Sons, Inc., London, Chapman & Hall, Ltd., 1933. Price $4.50.

Elements of Power Generation, by Arthur M. Greene, Jr., 314 pages, illustrations, 15.5 × 23.5 cms., New York, John Wiley & Sons, Inc., London, Chapman & Hall, Ltd., 1933. Price $3.25.

Heat, by James M. Cork, 279 pages, tables, illustrations, 15 × 24 cms., New York, John Wiley & Sons, Inc., London, Chapman & Hall, Ltd., 1933. Price $3.00.

Other Worlds, by Edwin Lincoln Moseley, 230 pages, illustrations, 13 × 19.5 cms. New York, D. Appleton & Company, 1933, Price $2.00.

Der Weg zu uns selbst eine Ganzheitslehre der Lebens-, Wohn- und Stadt-Bau-Kultur Band: das Lehrgebaude, von Richard Scharff, 78 pages, 17 × 23.5 cms. Detmold, Meyersche Hofbuchhandlung, 1933. Price 3 marks.

Actualites Scientifiques et Industrielles, No. 49, La Philosophie Scientifique, par Hans Reichenbach, 43 pages, 16.5 × 25.5 cms. 1932. Price 10 francs. No 50, Les Bandes Moleculaires dans les Spectres Stellaires, par P. Swings, 28 pages, tables, 16.5 × 25.5 cms., 1932. Price 7 francs. No. 51, Structures et Proprietes Optiques des Carbonates, par H. Brasseur, 25 pages, 16.5 × 25.5 cms., 1932. Price 7 francs. No. 56, Sur la Theorie du Rayonnement, par Eugene Neculcea, 24 pages, 16.5 × 25.5 cms., 1933. Price 7 francs. No. 57, Sur l'Absorption Exponentielle des Rayons du Radium, par MM. G. Fournier et M. Guillot, 37 pages, diagrams, 16.5 × 25.5 cms., 1933. Price 10 francs. No. 58, La Recherche Scientifique, par Jean Perrin, 24 pages, 16.5 × 25.5 cms., 1933. Price 6 francs. No. 59, La Diffraction de la Lumiere par des Ultra-Sons, par L. Brillouin, 29 pages, 16.5 × 25.5 cms., 1933. Price 10 francs. Paris, Hermann et Cie.

National Advisory Committee for Aeronautics, Technical Notes, No. 460, Full-Scale Wind-Tunnel Research on Tail Buffeting and Wing-Fuselage Interference of a Low-Wing Monoplane, by Manley J. Hood and James A. White, 13 pages, plates, figures, 20 × 26 cms. Washington, Committee, 1933.

Canada Department of Mines, Investigations of Fuels and Fuel Testing, 1930 and 1931, 166 pages, tables, plates, charts, 16.5 × 24.5 cms., Ottawa, King's Printer, 1933.

Ontario Department of Mines, Forty-first Annual Report, 52 pages, illustrations, maps, 16.5 × 24.5 cms., Toronto, King's Printer, 1933.

CURRENT TOPICS.

Pondering the Imponderable.—(*Science*, 77, 397.) PROFESSOR OTTO HAHN of the Kaiser Wilhelm Institute, in an introductory public lecture, traced out that border line separating ponderable matter from that imponderable. His course led through the realms of physics, chemistry and biology and the path was plotted by a variety of interesting facts: some new, others that have been mentioned only infrequently.

Today there are analytical balances that will weigh masses of twenty grams to within a millionth of a gram (one twenty-eight-millionth of an ounce). However, such minute accuracy is still inadequate for, as we shall see, many ponderous changes are wrought by imponderable entities. Necessity is the mother of invention and, when required, scientists can devise, other ways and means of accurately determining unweighable amounts. For illustration, take the attempts to extract gold from sea water. Early investigators had placed the gold content of sea water at five to ten milligrams of gold per ton of water (one part in two hundred million). This would mean a total of eight billion tons of gold in all the seas. However, recent experiments by Haber showed that the gold concentration in sea water was actually only one-thousandth as much as originally supposed. All this work led to the development of a microscopic method for determining with certainty a ten-millionth of a gram or less. A similar means was used by Alfred Stock for detecting as little as hundred millionths of a gram of mercury in the saliva, in urine, and in exhaled air as a result of teeth having been filled with poorly made amalgam dental fillings.

It is not so difficult to understand how quantities of a substance as small or smaller than a hundred-millionth of a gram can often exert such widespread effects when we realize that even a quantity that small, represents a cluster of around a million million molecules. Some idea of a molecule's dimensional insignificancy may be gained by considering a perfectly evacuated electric light bulb with an opening in it so fine that one million molecules of air enter in one second. Then one hundred million years must elapse before the bulb will fill with air to atmospheric pressure. Or again, suppose that in some way each of the molecules in the two hundred grams of water contained in an ordinary drinking glass could be made visible, could be labeled or tagged. If this glassful of water were then

poured into the ocean and time allowed for its molecules to be thoroughly distributed throughout the waters of the globe, then a glass of water taken at any point would contain two thousand of those tagged molecules. Once more: In a gram of uranium, ten thousand atoms are transformed into lead per second yet seventy-one million years must elapse before one-hundredth of a gram of lead is formed.

The fact that the atoms and molecules of various substances are capable of emitting characteristic rays of light has made possible the detection of as little as a two hundred thousand-billionth of a gram. Some dyes such as fluorescein can be detected at infinitely great dilutions. A solution of twenty-two pounds of this dye was sunk in the headwaters of the Danube, whereupon it showed up sixty hours later in a tributary of the Rhine.

Sense of smell is another remarkable means for detecting minute quantities of such substances that affect the olefactory nerves. The nose is capable of detecting one part of a mercaptan in fifty thousand million of air; an amount equal to one four hundred and sixty thousand millionth of a gram. Two Swiss naturalists performed the experiment of raising the caterpillar of a butterfly in the city of Zurich where it spun its cocoon and emerged the following spring a female butterfly. Imprisoned in a room with windows open it was only two days when more than one hundred males of the same species had gathered in the room having traveled from the forests several miles away. Such is the power of smell.

Immeasurably dilute solutions of metals such as copper or silver are found to destroy or prevent the growth of certain plants and lower organisms. Witness the recent adoption of finely divided silver as a sterilizer of water, milk and other substances. The ancient Egyptians discovered that open wounds healed better and more rapidly if they were covered with silver plates. Bone fractures are often repaired with silver wire.

In the field of enzymes, vitamins and hormones, we have a class of substances that can exert mighty effects upon living organisms although they are present in almost infinitesimal amounts. A hundred-thousandth of a gram of thyroid secretion will overcome the suspended metamorphoses of salamanders. Tadpoles which fail to develop in iodine-free water grow more rapidly than normal if one part of thyroxine is added to five thousand million parts water. Certain tropical lilies cannot develop normally unless their water habitat contains a hundred thousandth to a millionth of boric acid.

Grain sprouts will not grow if their tips are cut off. These tips were found to contain a minute amount of growth-promoting hormone called "auxin." One fifty thousand-millionth of a gram is

sufficient to produce growth. Strangest of all was the discovery that every human being, regardless of age or sex, secretes in the urine an average of two milligrams of auxin daily, an amount far greater than what could be obtained from a thousand sprouts of grain.

Without a doubt radioactivity furnishes the means of detecting the presence of the ultimate particles of matter. A billionth of a gram of radioactive material can readily be detected through its effect upon a photographic plate. By means of the "Wilson cloud-chamber" one can render visible the presence of single atoms of which 6×10^{22} are required to weigh one gram. We are inclined to agree with the author that humans should be grateful that Nature has not extended the limit of visibility beyond the realm of weighability. If we could see how many imponderable nuclei of dirt, dust and disease are contained in the air we breathe the joy would be gone from life.

C.

If Alcohol Is Added to Gasoline.—(*Ind. & Eng. Chem.*, News Edition, 11, 117.) D. H. KILLEFFER has come to the front with a rather timely article which discusses the blending of ethyl (grain) alcohol with motor fuel as a means of Farm Relief. First it is pointed out that the petroleum industry will object to such a scheme for such reasons that the inclusion of alcohol in motor fuel will require, (1) changes in the distributing system, particularly the complete removal and continued exclusion of water from it; (2) policing of the distribution system to prevent recovery and diversion of alcohol; (3) the increase in price the addition and blending of alcohol will cause,—and (4) a corresponding quantity of motor fuel must necessarily remain unconsumed.

Let us first consider the method of manufacturing this alcohol and the probable costs involved. At the present, the cheapest raw material is molasses at 5 cents or less per gallon. About two and a half gallons are required to make a gallon of alcohol which sells at 28 to 29 cents in a highly competitive market. Such alcohol is of 95 per cent. grade and must be rendered absolute before mixing with the gasoline. The present cost of dehydration is about 10 cents, but for the huge quantities involved in this new application the cost probably would be reduced to around 2 cents. Therefore it is safe to assume that alcohol suitable for blending can be prepared from molasses at a cost of 30 cents per gallon.

However, if, as planned, the alcohol is to be produced from corn, then cost of raw material and processing will be considerably higher. A bushel of corn will yield 2.5 gallons alcohol but in processing, the

corn must be "mashed" and malted, both operations not required by molasses. If the price of corn reaches its objective of 60 cents then the cost of the anhydrous alcohol will be somewhere near 45 cents per gallon or 50 per cent. higher than that made from molasses.

To persons not well aquainted with those physical and chemical properties peculiar to alcohol and to gasoline the mere act of blending might seem to offer no difficulties whatsoever. This is only partially true. Mixtures of gasoline and pure alcohol free from water are quite stable but as soon as water is introduced, even in minute amounts, the mixture tends to separate into two layers, one consisting of alcohol and water and the other gasoline. Mixtures containing relatively large proportions of alcohol are more stable to water additions than those containing small amounts, and all mixtures are less sensitive to water when warm than at lower temperatures. The sensitiveness of water-free alcohol-gasoline mixtures are such that at 68° F., a mixture of 3 parts alcohol and 97 parts gasoline separates on the addition of 0.02 per cent. of water; 10 alcohol and 90 gasoline, 0.3 per cent. water; 25 alcohol and 75 gasoline, 1.12 per cent. water; and 50 alcohol and 50 gasoline, 1.42 per cent. water. These figures are based on average commercial gasolines. It is possible that certain cracking processes applied to various types of crudes may produce a fuel of improved stability. Also it may be found economical to add such substances as isobutanol, normal butanol or coal-tar benzene which are able to increase the stability of gasoline-alcohol mixtures.

Of course, many car owners are wondering what differences they can observe between the straight gasoline and that of a mixture. Well, a consumption of 200 million bushels of corn annually will make enough alcohol to permit a 3 per cent. mixture. The average motorist scarcely would be able to distinguish a difference in the operation of his car, for such a mixture would differ less from the original gasoline from which it was made than the differences between commercial gasolines made by different makers. There would be a slight increase in the antiknock value of the fuel and the calorific or mileage value slightly diminished. The ultimate price to the consumer certainly should be greater since the addition of 3 per cent. alcohol will nearly double the present cost at the refinery. If 600 million bushels of corn are to be consumed then the blend will contain 10 per cent. alcohol as the maximum. This mixture probably would show an increased antiknock rating of about 4 to 5 octane numbers. Most drivers would not detect this difference since there is difficulty in spotting a difference of 10 to 12 in the octane rating of present brands of gasolines unless the difference occurs within a range critical for the engine. Such a blend would have a

mileage value about 4 per cent. lower than commercial gasolines but probably would be noticed only by fleet owners and others who keep careful checks on the mileage obtained from their fuels. The refinery cost of this blend probably will be trebled.

C.

Industrial Notes.—(*Ind. & Eng. Chem.*, News Edition.) A new vacuum cooling system has been developed for the cooling of water and a variety of miscellaneous liquids. No ammonia or other refrigerant is used, the cooling being accomplished simply by spraying the liquid into a high-vacuum chamber, where a small portion is evaporated and the balance cooled at the expense of the latent heat of evaporation. Evaporation of 3 per cent. of water produces a cooling effect of 30° F. The vacuum is produced by allowing steam to condense. Both first and operating costs are relatively low.

Metallic iron and its oxides generally are present as impurities in many mineral products such as asbestos, mica, glass and sands. Iron and its black ferric oxide ($FeO.Fe_3O_4$) are distinguishable from the more common ferrous (FeO) and ferric (Fe_2O_3) oxides in that the former possess magnetic properties. A magnetic device for determining magnetic iron impurities up to 5 per cent. has proved particularly adaptable in the examination of asbestos. It is essentially a differential permeameter with an indicating arrangement. The permeameter consists of a coil having a high magnetic field and in which are located two smaller similar coils connected to the indicator with their induced voltage in opposition. The specimen to be examined is placed in one of the secondary coils thus disturbing their electrical equality which is translated into per cent. magnetic impurities by the indicator.

By using a recording color analyzer less than one millionth of an ounce of iron can be quantitatively determined. The metal is converted into red ferric thiocyanate, the intensity of color in solution being proportional to the amount of iron dissolved.

There are available for general use one-sixth horsepower electric motors that are protected against burning out. An integrally mounted thermostat opens the circuit when the motor gets too hot and restarts the motor after it has cooled.

Pumps can now be supplied with check valves fitted with automatic flow switches whose purpose is to shut down the pump should it lose its water or other fluid during operation. Losing water causes a lowering of the valve flap, opening the switch which in turn is connected to the low-voltage coil of the motor starter and thus the pump is stopped.

Improvements in a pyrometer controller include a socalled "deoscillator." The object of this device is to impress onto the thermocouple circuit a slight additional e.m.f. that augments the thermocouple e.m.f. when the temperature is low and opposes it when the temperature is high. This causes the controller to close either the high or low circuit a little in advance of the actual temperature demand.

Now we have fuses of platinum wire drawn thirty times finer than a human hair and ranging from 0.01 to 2 amperes capacity.

Seamless tubing of silver, gold, pure nickel or stainless steal in a variety of sizes is now being supplied by a manufacturer who also undertakes the fabrication of silver castings and valves.

C.

Research That Pays Profits.—From the Mellon Institute of Industrial Research comes a reprint: an Abstract of the Twentieth Annual Report of the director, E. R. WEIDLEIN. For many years the Institute has been the recipient of considerable numbers of industrial research fellowships the products of which have returned to the donors values many times in excess of the original investment. Evidence of the confidence held by the industry at large in research institutions of this type is exemplified by the report that throughout the last fiscal year 67 industrial fellowships requiring the services of 109 fellows and 28 assistants were pursued under the foster guidance of the institute. Results of some of the industrial fellowship researches are worth mentioning:

A twelve-month survey on the occurrence of carbon monoxide in Pittsburgh was made. At street intersections, the concentration of gas was at no time considered objectionable, but undesirable conditions were occasionally found in parking garages. In the investigation of solar ultra-violet radiation, the effect of the marked reduction in industrial activity as well as that of winter heating plants were plainly evidenced.

The work on "New Building Materials" has resulted in the production of a cement-coated steel sheet that has high weather resistance. This building panel consists of a core of asphalt and asbestos-protected steel enveloped with a cement possessing novel properties. Earlier developments under this fellowship include a "metallic adhesive" and the "keystone-beam" steel flooring.

One fellowship has been occupied with the development of new varieties of strained vegetables and a comparison of their nutritive values when prepared by factory methods with the various procedures used in the home, paying special reference to the vitamin content.

Work on organic syntheses has resulted in the development of methods for producing amines; preparation of new types of glycol compounds especially for the lubrication of textile fibers such as silk, rayon and wool. Attempts to determine the specifications for an ideal plasticizer for nitrocellulose and cellulose acetate were coupled with work on new types of plasticizers and resins.

In the field of petroleum production, special emphasis has been directed toward the difficulties in pipe-line shipment of crude oil in cold weather. The fluidity of a cold crude oil not only depends upon the temperature but upon the shearing stress induce in the fluid; the same principles must be applied when studying rotary drilling muds. Corrosion studies have led to the discovery of materials that decrease effectively hydrogen sulfide corrosion of oil-well equipment. This investigation is coupled with a study of the chemical treatment of wells to increase oil production.

Research on leather has resulted in developing a new type of chrome-tanned Vici kid leather that has increased durability, resistance to scuffing and water-proofness. The secret of success lies in the introduction of a lubricating material during the tanning operation. It gives a flexible yet non-stretchable leather that wears exceptionally well and eliminates a finishing operation on the shoes after they are made.

Attempts to develop new uses for sugars has resulted in the preparation of a variety of sucrose compounds one of which is viscous enough to serve as an adhesive; another is soluble in petroleum distillates while others may serve as plasticizers. The use of sugar in the manufacture of sand-lime brick has been successful and it is now being employed in some mid-western sand-lime brick plants.

C.

And Now Zeolite For Treating Sewage.—(*Chem & Ind.*, 52, 347.) Zeolite, usually described chemically as a sodium alumina-silicate, is used extensively as a base-exchange water softener. Salts of calcium and magnesium generally comprise the hardness in water and zeolite has the remarkable ability of exchanging its sodium for the basic elements of these salts. Thus, the water is softened through having these calcium and magnesium salts transformed to those of sodium. Conversely, the calcium and magnesium may be removed from the zeolite by treatment with a strong solution of common salt.

As one might suspect, a zeolite does not limit its activity to those three basic elements named above. Apparently it can be encouraged to react with a variety of alkaline substances either organic or inorganic. This property has led to the development of

an improved scheme of sewage treatment and disposal in which zeolite plays a very important part. Sewage is passed through coarse and fine screens, to remove the coarser suspended solids, into a tank where ferric sulfate is added, and air is passed continually through the liquid to keep the iron oxidized. Lime is added in a second tank, equipped with a flocculating mechanicism and the time of flocculation as well as the hydrogen-ion concentration, is rigorously controlled.

The liquid is then passed into a "clarifier," where the sludge settles and the supernatant liquor overflows onto the zeolite beds. The zeolite bed not only acts as a base-exchanger but a filter as well. Thus the supernatant liquor has its remaining suspended matter removed in addition to the important operation of removing all the putrescible organic compounds that have escaped precipitation. The basic nitrogen of these compounds is exchanged for the sodium in the zeolite. About 16,000 lb. of zeolite is required per million gallons of sewage treated. After remaining from 10 to 12 hours in contact with the zeolite, the liquid is passed to a second bed of the same material, and the original bed is regenerated by washing with a concentrated (20 per cent.) solution of common salt. The basic nitrogen is thus transferred to the salt solution and this is treated with lime and distilled. The ammonia so liberated is recovered and the salt solution may be used over again.

The process was developed in a small plant with a daily capacity of 2,500 gallons of sewage. It is now proposed to continue the investigation in a 25,000 gallon per day plant. It is believed such a plant will not occupy more than about one-half of the area required by other types of plant giving equal purification; also that a plant of 50 million gallons, capacity, or more, will cost about two thirds that of an activated-sludge plant of similar capacity.

C.

Kjeldahl Digestion Apparatus.—In the determination of nitrogen by the Kjeldahl method, the organic compound is first digested with concentrated sulphuric acid and other reagents in order to convert its nitrogen into ammonia. During this digestion an irritating and corrosive mist of the acid is evolved. An elaborate apparatus of lead is usually used to collect this mist and carry it out of the building. ABRAHAM HENWOOD AND RAYMOND M. GAREY (*Science*, 1932, LXXVI, 524) have devised a simple apparatus to retain the mist in the flask. It is a tube of alundum which snugly fits the neck of the Kjeldahl flask, is closed at its bottom, and is flanged at its top. This tube permits the free exit of steam, carbon dioxide, sulphur dioxide, and other gases, but acts as a condenser for the

mist of sulphuric acid and prevents its escape. After digestion has been completed, the tube may be washed with water to recover any traces of ammonium salts which have been carried into it with the spray. The inventors describe the device as simple, cleanly, convenient, inexpensive, and efficient.

J. S. H.

Electrometric Method for the Detection of the Relative Freshness of Fish.—MAURICE E. STANSBY AND JAMES M. LEMON (*Ind. and Eng. Chem.*, Analytical Ed. 1933, V, 208–211) have devised an electrometric test to determine the relative freshness of haddock. The method is based on the measurement of buffer capacity. The finely ground meat is well mixed with water, quinhydrone is added, and the mixture is titrated, first to a pH of approximately 6.0 to measure the amount of end products of bacterial decomposition (secondary decomposition), then to a pH of approximately 4.3 to obtain an inverse measurement of the primary changes or protein hydrolysis.

J. S. H.

A Thirteenth Century Book on Stones.—Under this title, MARY LOUISE FOSTER (*Jour. Chem. Ed.*, 1933, X, 369–372) describes the manuscript known as "El Lapidaris de Alfonso el Sabio" which was prepared in 1278 by direction of Alfonso X of Aragon, and is based on both Arabic and Chaldean sources. Among the minerals and rocks described are magnetite, gold, silver, lead, mercury, pearls, limestone, asbestos, and bezoar. The four folios describe 492 stones. The bezoar was regarded as a panacea in the Middle Ages; today it is classified as a gastrolith or gastric calculus, a mineral mass deposited in the stomach of an animal. Similar intestinal calculi are also known.

J. S. H.

Substitute for Equivalent Weight.—The equivalent weight of an element (or compound) is obtained by dividing its atomic (or molecular) weight by its active valence. CHARLES N. OTT (*Jour. Chem. Ed.*, 1933, X, 312) suggests that the term "equivalent weight" be replaced by "univalent weight" since it actually represents that weight of an element or compound which might be considered to have a valence of 1.

J. S. H.

New Possible Source of Vitamin D.—ROGER W. TRUESDAIL AND HELEN J. CULBERTSON (*Ind. and Eng. Chem.*, Industrial Ed.,

1933, XXV, 563–564) have studied the occurrence of fat-soluble vitamin D, which prevents rickets, in the oil of the California pilchard or sardine (*Sardinea caerulea*) and the tuna (*Neothunnus macropterus*). Their results indicate that, with improved methods of refining, edible tuna oil may be of therapeutic value, in the same manner as cod liver oil.

J. S. H.

Sweet Potato Starch.—The researches of F. H. THURBER (*Ind. and Eng. Chem. Ind. Ed.*, 1933, XXV, 565–568) indicate that starch manufactured from cull sweet potatoes is quite suitable for sizing cotton textiles, since it possesses satisfactory coating and penetrating qualities for cotton yarn. It has a relatively uniform viscosity over long periods of heating; therefore a uniform sizing bath can readily be maintained.

J. S. H.

Edgar Fahs Smith Memorial Library.—EVA ARMSTRONG (*Jour. Chem. Ed.*, 1933, X, 356–358) describes this collection of books, journals, pictures, manuscripts, etc., on the history of chemistry, which is a valuable source of original material for research workers in this field. It was begun by the late Provost of the University of Pennsylvania, and has received numerous additions since his death.

J. S. H.

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